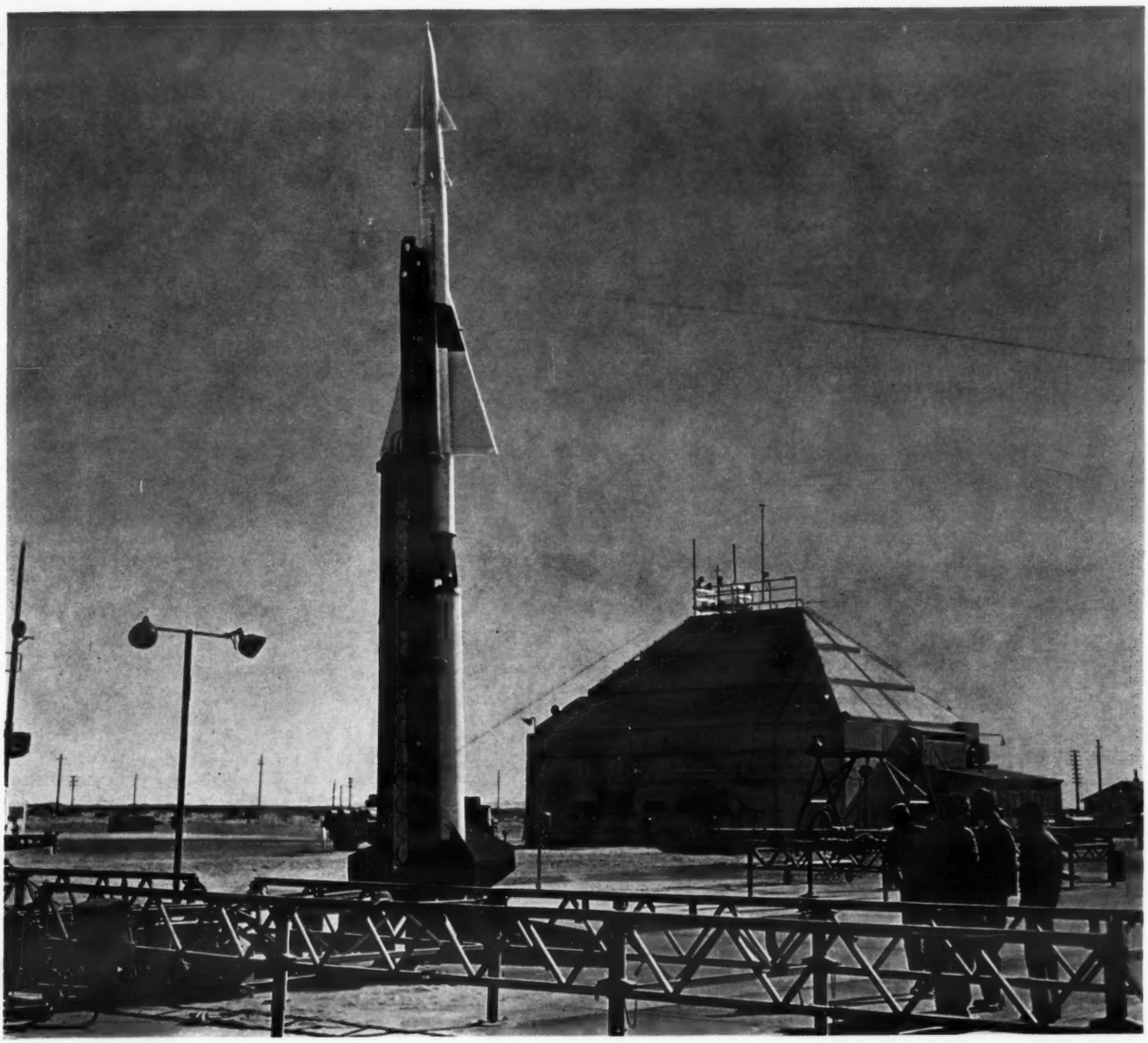
INTERAVIA

REVIEW OF WORLD AVIATION



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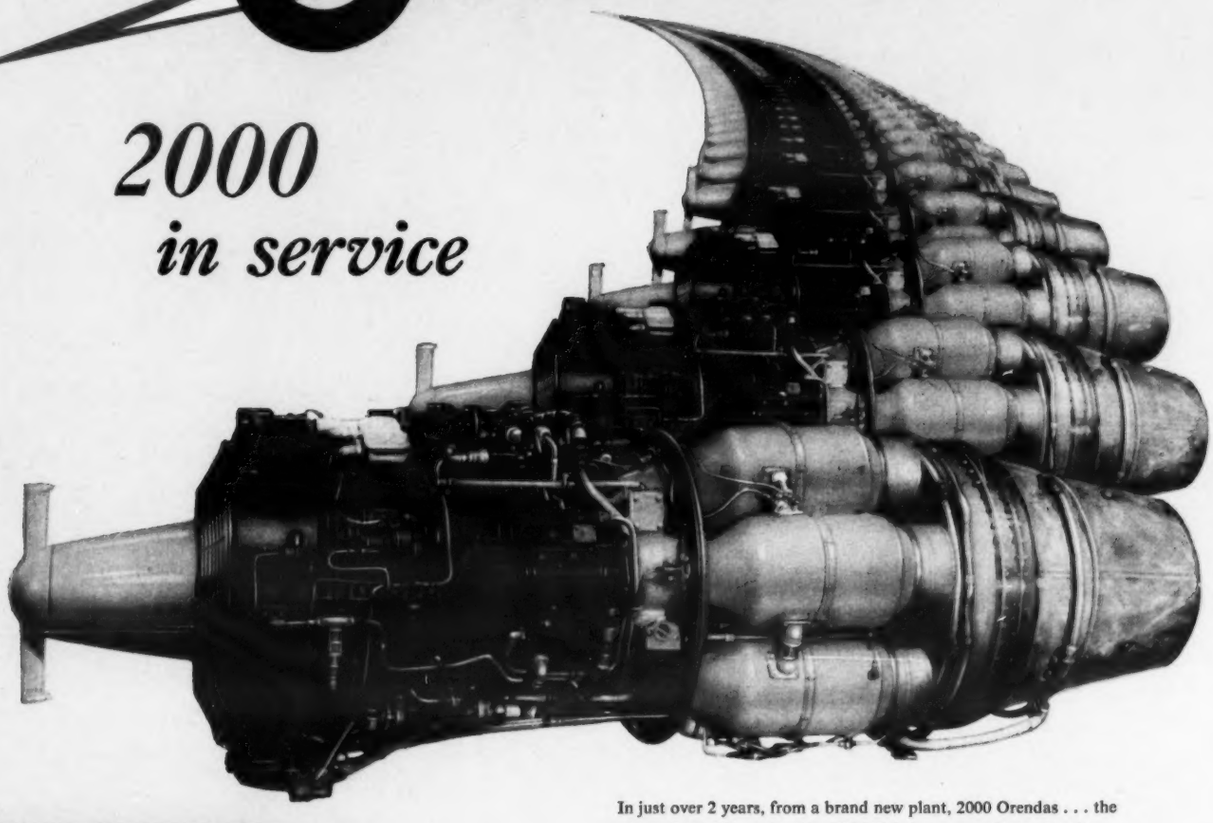
Soviet Re-Equipment Plans

VOLUME X 5 1955

ORENDAS...

2000 in service



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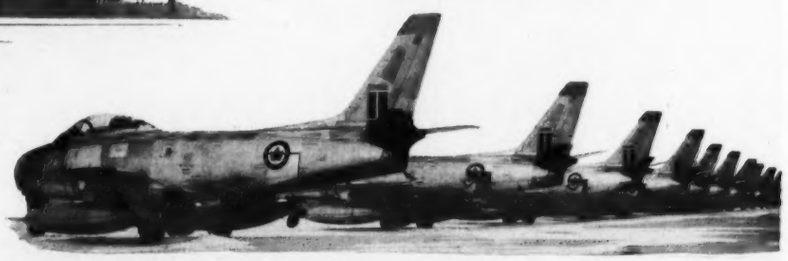

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Volume X No. 5 1955

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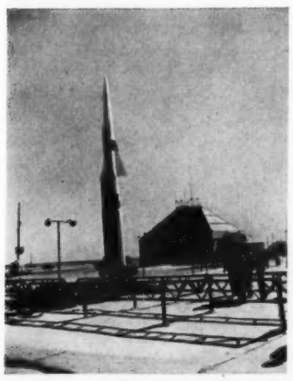

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A Douglas Nike *anti-aircraft guided missile ready for launching at White Sands Proving Ground, New Mexico.*

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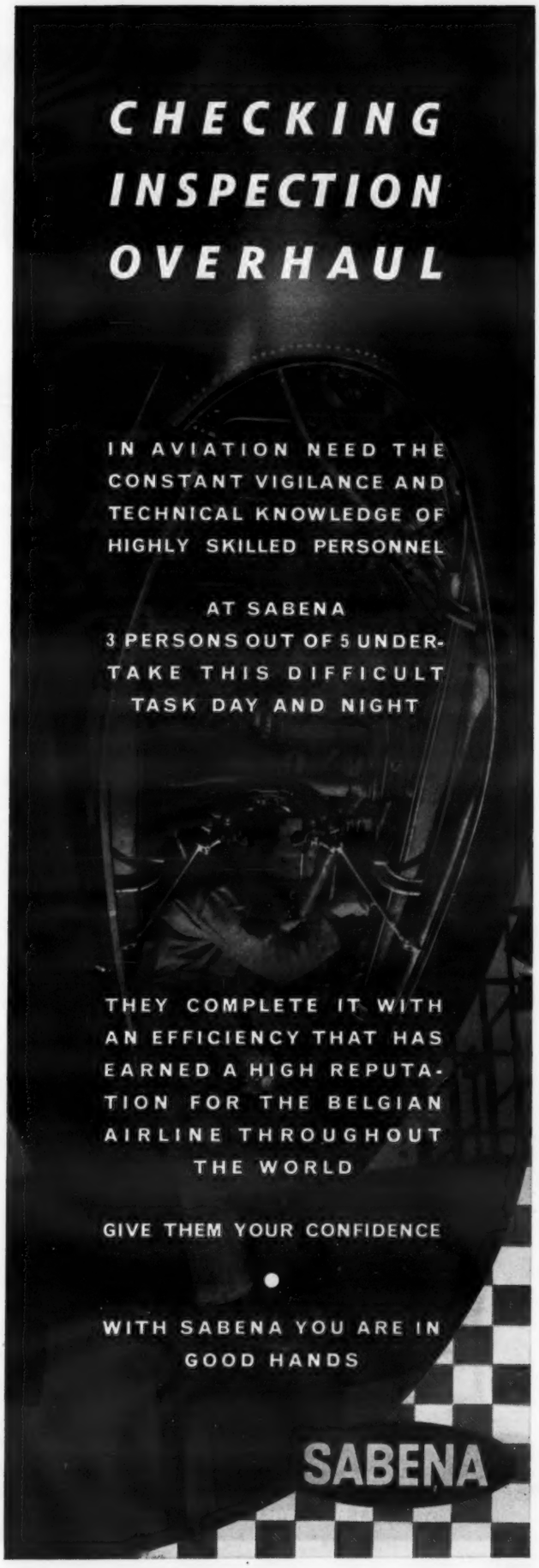
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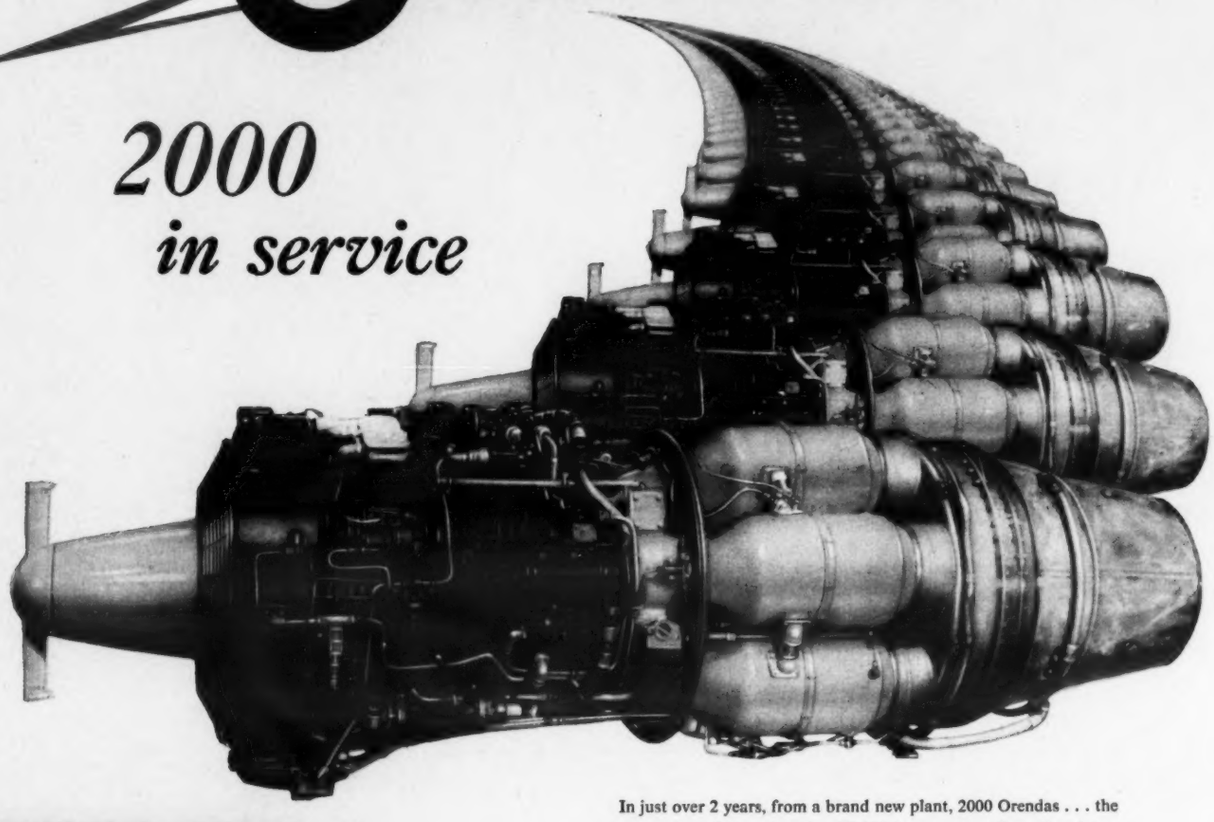

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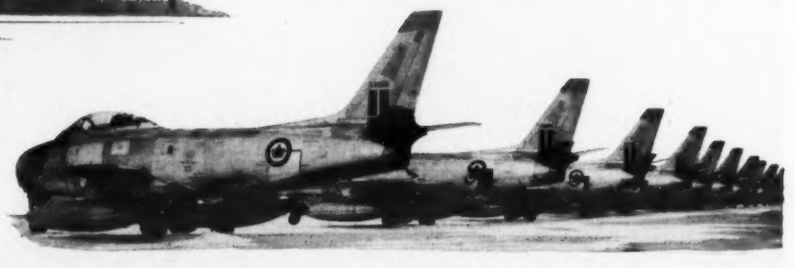

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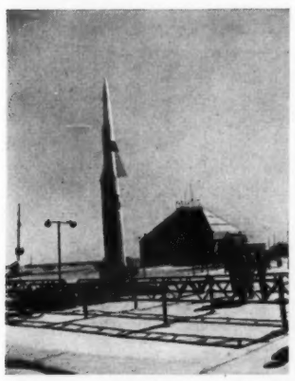

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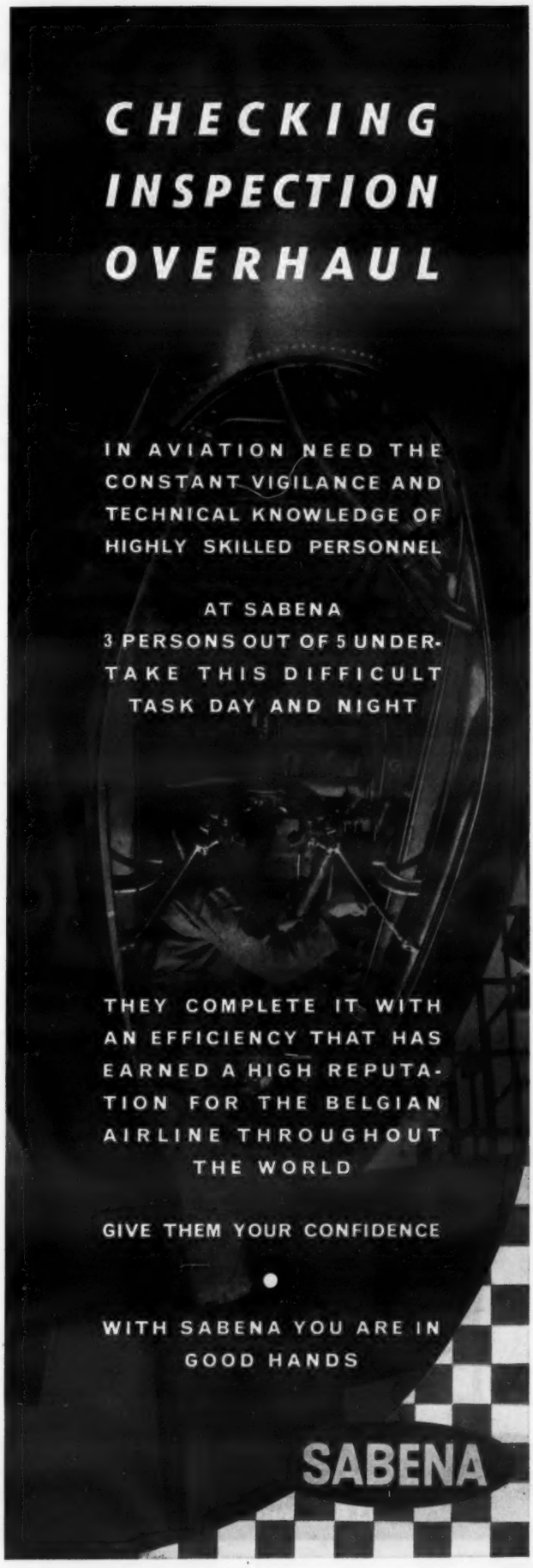
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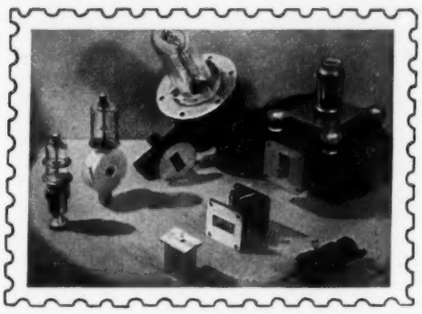

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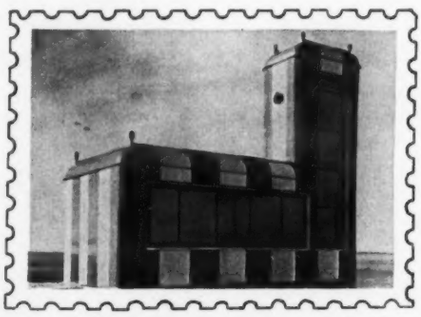

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ROGER. LEAVING 3000.
PORTABLE GCA RADAR SPAR UNIT
YOU'RE OVER THE OUTER MARKER AT 2000. START A NORMAL RATE OF DESCENT.
ROGER.
EVERY TIME WE MAKE A GCA LANDING, I'M IMPRESSED BY SPAR'S ACCURACY.
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FLIGHT OPE ATIONS

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ROGER. NORTHERN 340— CONTACT PORTLAND RADAR ON 114.7 MEGACYCLES.
NORTHERN 340—THIS IS PORTLAND RADAR. WE HAVE YOUR POSITION REPORT. TURN RIGHT HEADING 120 FOR IDENTIFICATION.
NORTHERN 340— ROGER.
TURN LEFT HEADING 040. YOU ARE NOW 100 FEET HIGH ON GLIDE PATH. INCREASE RATE OF DESCENT.
COURSE O.K. YOU ARE NOW BACK ON GLIDE PATH—RESUME NORMAL RATE OF DESCENT.
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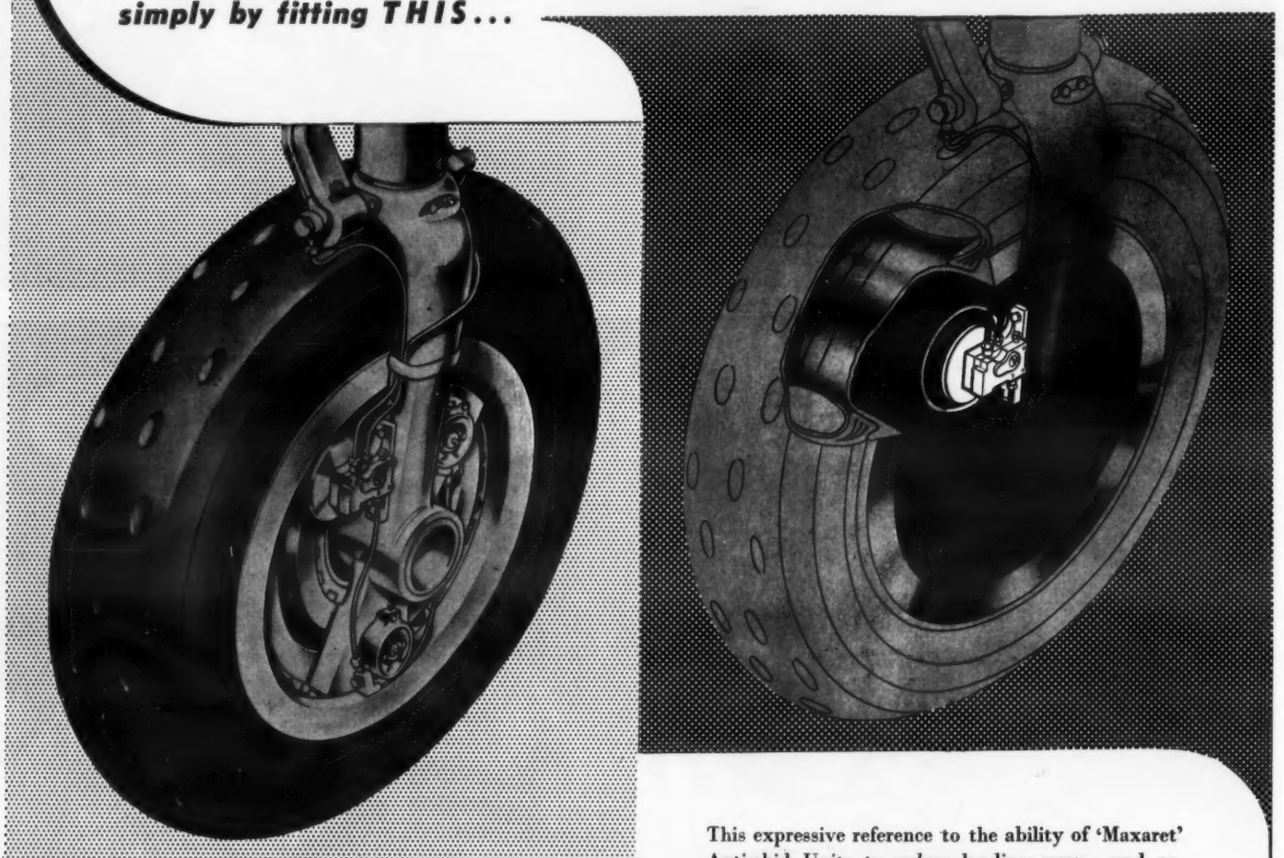

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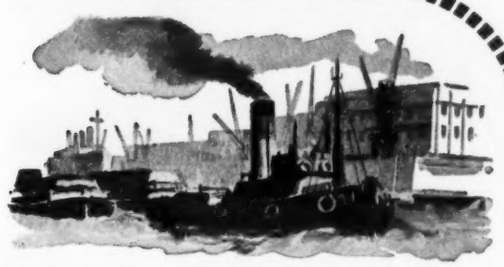

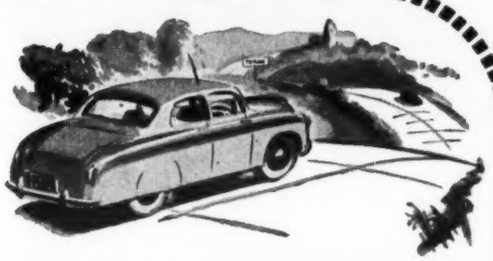

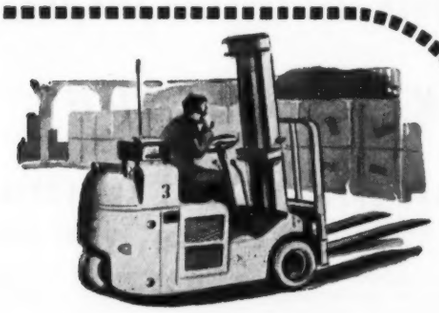

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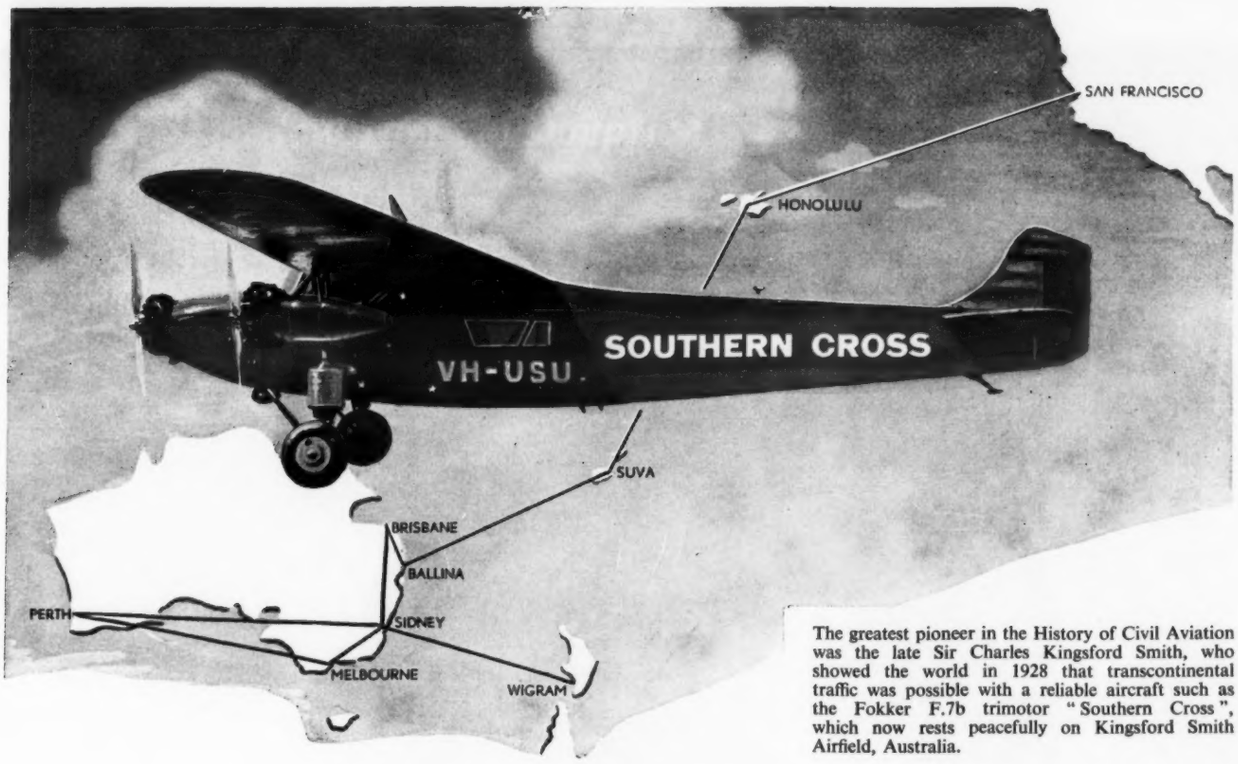

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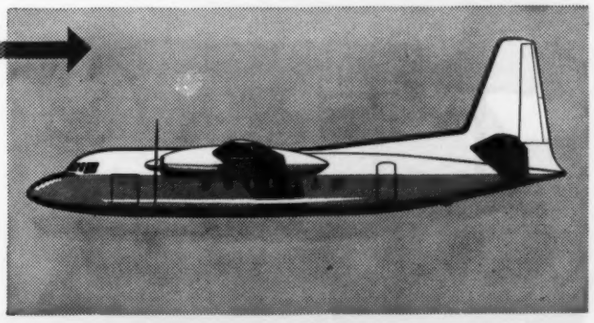

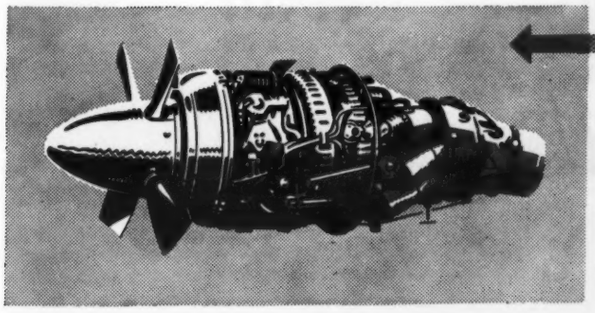

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with which the "Friendship" is powered are the most reliable propeller-turbines available for this type of aircraft. They allow economical operation in all climates and safe and vibrationless flight at 20,000 ft.

* * *

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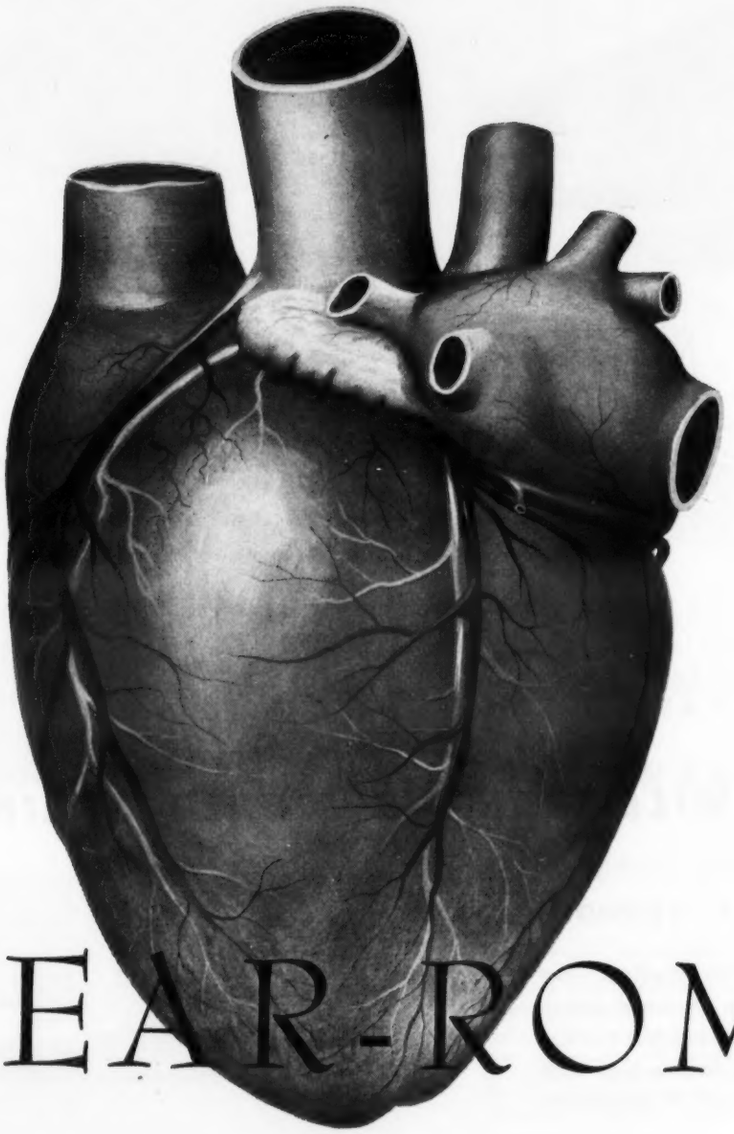

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more facts about the Eland

* High aerodynamic efficiency—3,000 e.h.p. in a maximum diameter of 36 inches.
* Low specific weight—0.52 lbs./e.h.p.
* Easy maintenance—independent unit construction.
* Ease of control—single lever control, with manual over-ride, guards against engine over-speeding and over-fuelling.
* Automatic temperature compensation.
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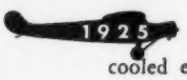
KLM

THROUGHOUT THE YEARS - THROUGHOUT THE WORLD

Some remarkable pioneering feats:

KLM inaugurates the world's oldest air service still maintained by the same company: Amsterdam-London.

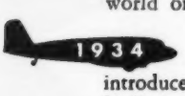
KLM opens the first air traffic booking office in the world.



KLM is the first to make use of air-cooled engines and all-metal propellers, also since 1920 the first to introduce to the world the Fokker passenger planes which later on became the most widely used commercial aircraft in the world.

1927 KLM makes the world's first intercontinental charter flight: Amsterdam-Jakarta and -Khartoum.

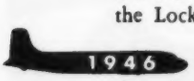
KLM opens the longest air route in the world of that time: Amsterdam-Jakarta.



KLM, as first airline outside the U.S., introduces the all-metal DC-2, wins the London-Melbourne Air Race handicap section.

1936 KLM is the first European company to purchase the world's most widely sold commercial aircraft: the DC-3.

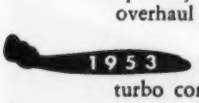
1943 KLM, as first non-U.S. carrier, orders the Lockheed Constellation.



KLM, despite its war-shattered organization, is the first European airline company after the war to open a regular Trans-atlantic service to New York.

1948 KLM is the first European company to put the Convair Liners into service.

1950 KLM is the first European airline to be specially authorized by the U.S. Government to overhaul aircraft of U.S. airlines.



KLM is the world's first airline to operate the turbo compounded Lockheed Super Constellations.

KLM
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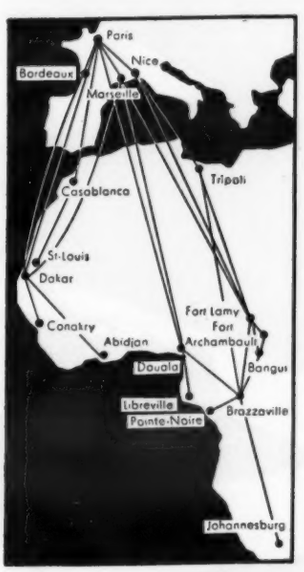
Wherever you go in French Africa

U.A.T. goes too



• Where are you going in Africa ? A large centre ? A small place in the bush ? U.A.T. goes there too. It will take you there in a few hours.

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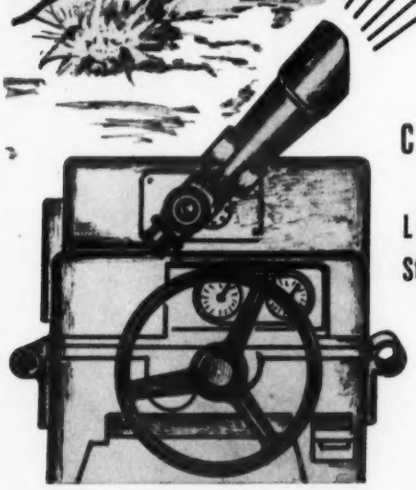

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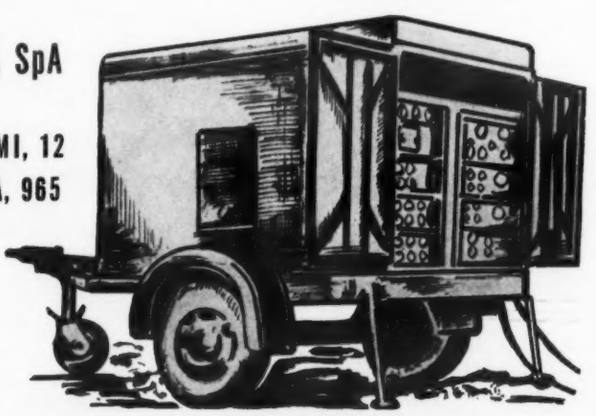
Stabilimento: VIA TIBURTINA, 965



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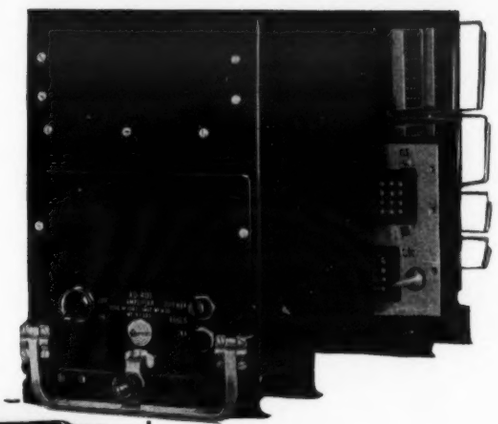
Simultaneous mixing of four channels each having its own volume control: intercommunication plus three selected services.



Above is the amplifier unit and the junction unit which serves as the backplate for the mounting rack of the amplifier unit, and thus eliminates cable connections between these two units. A main station box is shown on the left.

Features

- Self-contained power unit housed in amplifier unit.
- Detachable chassis arrangement and robust construction for ease in servicing.
- Lamp signalling between all station boxes.
- Emergency override facilities.

More than forty Airlines and twenty Air Forces fit Marconi air radio equipment. Marconi airport installations are in use throughout the world.

A minor station box is shown above. All units are designed to fit standard aircraft racking and for easy access in servicing.

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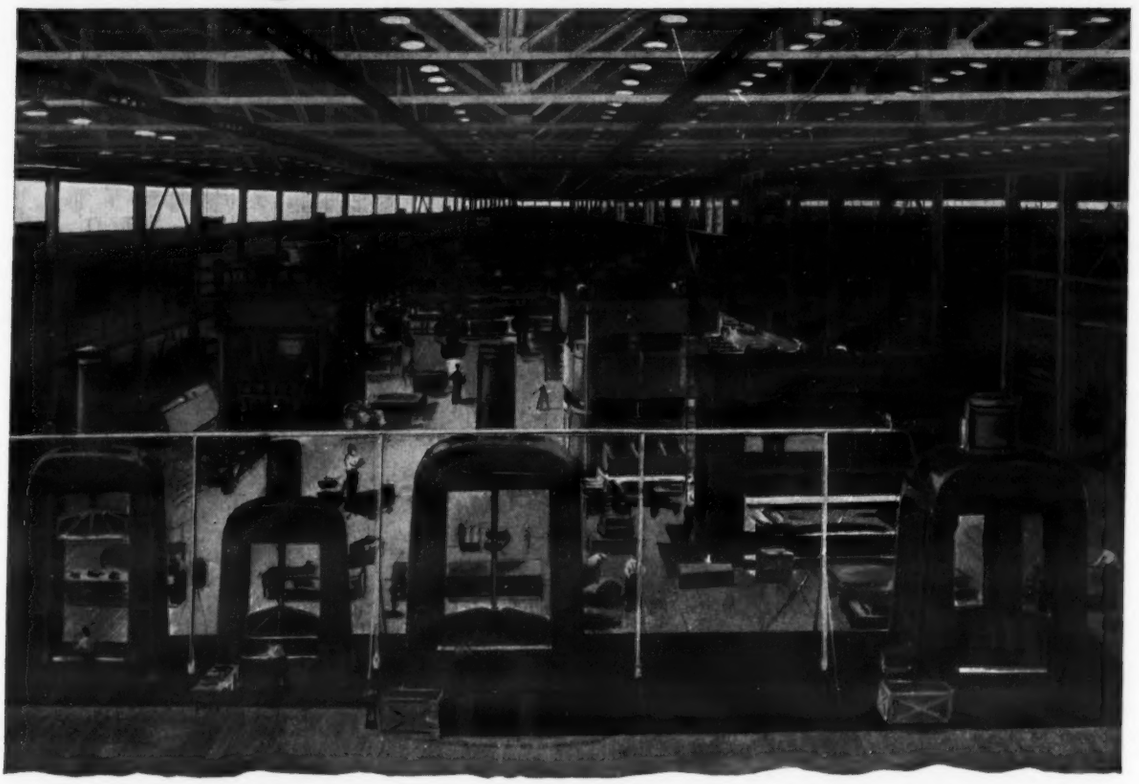

Equipment COUNTS – AT CANADAIR

One thing which is quickly apparent to visitors . . . Canadair is well equipped. Canadair's facilities include machines and processing equipment geared for big and small jobs . . . machines capable of transposing raw materials into all categories of parts, from the simplest — involving two operations — to the most complex valve-body fabrication involving a great number of different and distinct operations.

Wherever one moves throughout the two and one-half million square feet of covered factory space, the evidence is there . . . department by department, Canadair's equipment equals that of any aircraft plant of comparable size in the world. A new engineering development and test laboratory, for example, houses one and one-quarter million dollars worth of the latest instruments and equipment . . . some unique to this country.

From training planes to airliners . . . from jets to guided missiles . . . Canadair is indeed equipped to undertake any assignment with confidence — a good reason why people who know say "You can count on Canadair."

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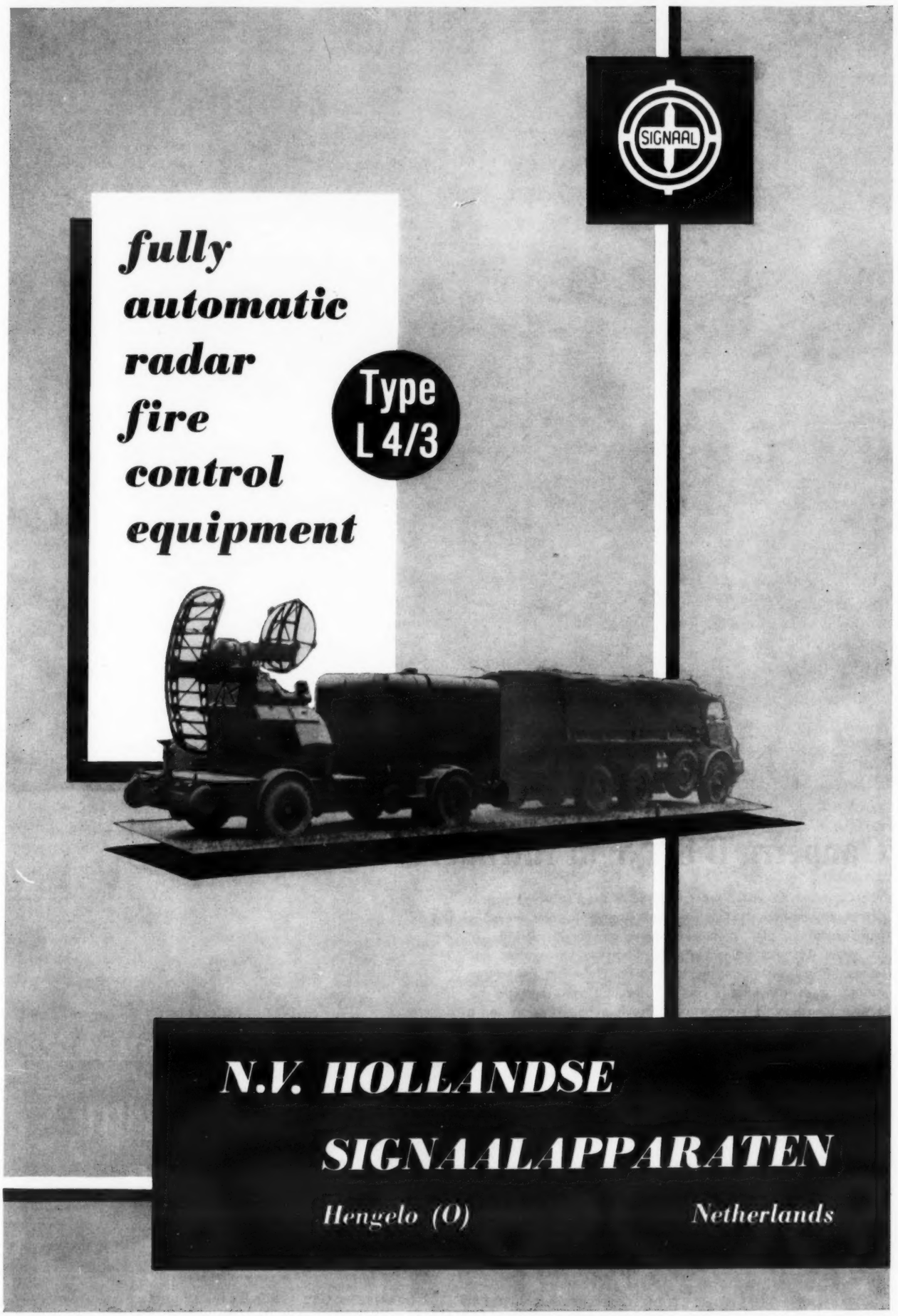
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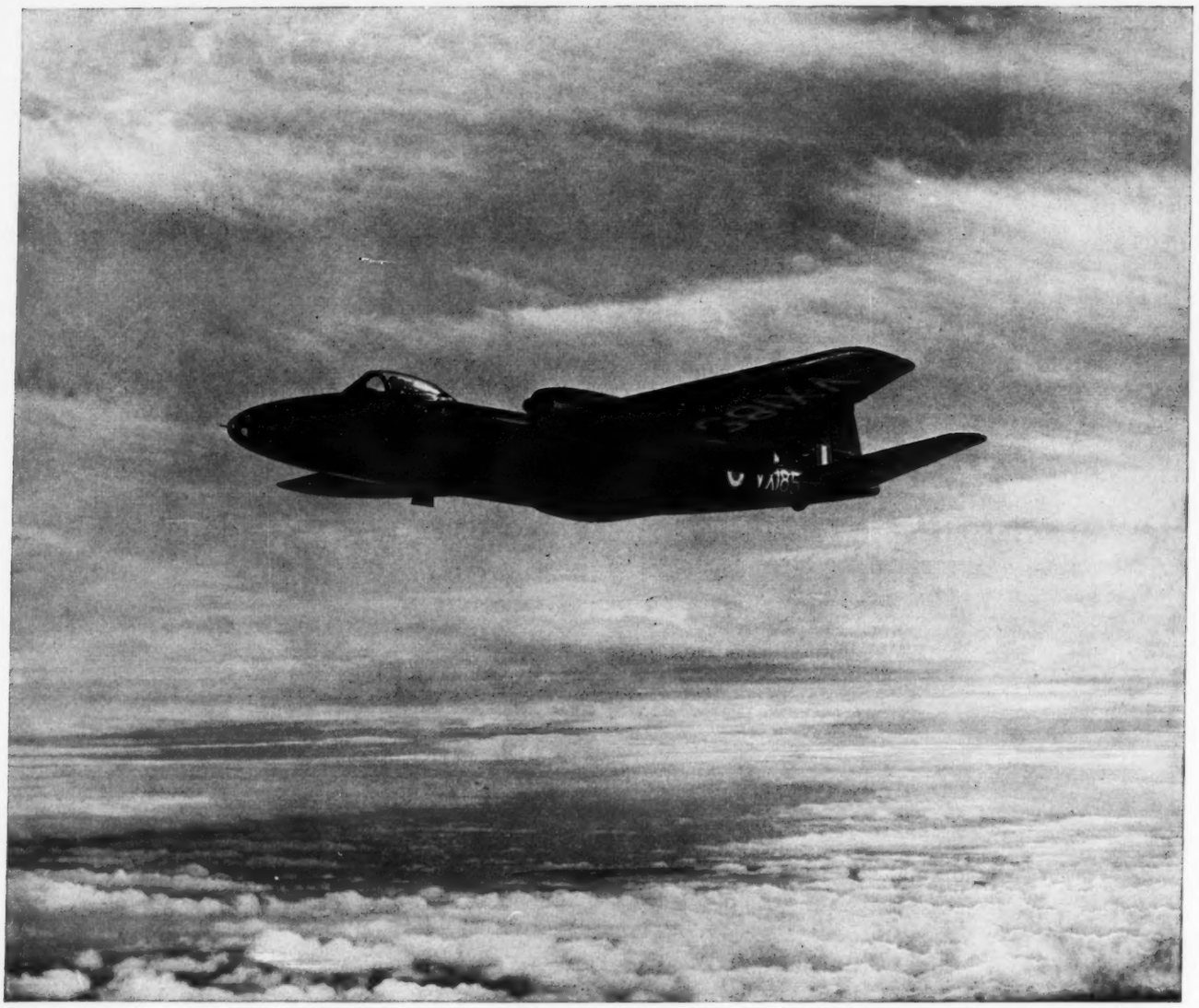

Canberra B 8 'Night Intruder'

The Canberra B 8 is the most versatile of the Canberra series. It can readily be converted to perform a number of rôles, including night intrusion, high altitude bombing and target marking. In its Night Intruder rôle it carries underwing armament and forward-firing cannon in the bomb bay. The offset fighter-type canopy gives the pilot a superb all-round view and the re-designed navigator's compartment provides better vision and a wider range of navigational aids.

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INTERAVIA

Deadline Notes

No. 5, 1954

SECOND INTERAVIA ROCKET ISSUE IN JULY

The material received by the Editors on rockets and guided missiles was so extensive that it could not be compressed into one issue without discarding valuable articles. It has therefore been decided to prepare a second rocket issue, in July 1955, to be devoted primarily to questions of space travel and the earth satellite programme. Authors will include Prof. S. F. Singer (U.S.A.), General Aldo Urbani (Italy), Dr. Eugen Sänger (Germany).

AMERICAN AND RUSSIAN LONG-RANGE MISSILES

Air Force Secretary Harold E. Talbott and U. S. Air Force Chief of Staff General Nathan F. Twining have told a Senate Appropriations sub-committee that according to reliable intelligence reports, the Soviet Union has reached "certain important stages in nuclear development well ahead of our predictions". General Twining added that the U.S. Government is "placing the very highest priority" on the American inter-continental missile project, since the nuclear weapons which Russia already possesses and is producing "make Communist air power the number one threat to our security".

CANADIANS TAKE OVER N.A.T.O. BASE AT MARVILLE

The first wing of the Canadian No.1 Group, equipped with 60 Sabre V fighters, has taken over the new N.A.T.O. air base at Marville, France, one of Europe's most up-to-date bases, built in 18 months.

AMERICAN ORDERS FOR FIAT

Interavia's Rome correspondent reports that the Pentagon has agreed to three off-shore orders for Fiat: (1) assembly and production of parts for 70 North American F-86K jet fighters (roughly $ 9,000,000); (2) overhaul and maintenance of General Electric J-47 jet engines; (3) supply of three Fiat G.91 light ground attack aircraft, to be followed by 27 others (the United States will bear 8/9 of the cost, the Italian Government 1/9). - Fiat already holds an earlier off-shore order totalling $ 22,500,000 for the assembly of North American F-86Ks, which are to go to the N.A.T.O. air forces, including the Italian Air Force.

I.A.T.A.'s TENTH ANNIVERSARY

I.A.T.A.'s tenth anniversary was celebrated with a banquet at the Hotel Nacional in Havana, where the International Air Transport Association was founded on April 16th, 1945. Dr. Henry J. Gorecki, I.A.T.A. Treasurer, paid tribute to Dr. Luis Machado (now Director of the International Bank for Reconstruction and Development) who was a member of I.A.T.A.'s founding committee and presided over the 1945 meeting.

FIRST C.P.A.L. COMMERCIAL POLAR FLIGHT

Canadian Pacific Airlines has now followed Scandinavian Airlines System as second airline to operate regular services between America and Europe via the Arctic. First flight was made by a company Douglas DC-6B (51 passengers, 8 crew members) between Vancouver and London on April 12th.

PROXIMITY WARNING RADAR FOR U.S. COMMERCIAL AIRCRAFT

D. S. Little, of the Air Transport Association of America, has told a meeting of the Radio Technical Commission for Aeronautics that airlines are becoming interested in development of a collision warning radar to prevent ramming of ground obstructions and other aircraft. Little asked the electronics industry to co-operate on the project.

* From INTERAVIA's world-wide news service, including INTERAVIA AIR LETTER, the daily international aviation news digest. — No part may be reproduced without written permission.

LOUIS LESIEUX BECOMES AIR FRANCE MANAGING DIRECTOR

The Board of France's flag carrier and Minister for Public Works and Transport General Corniglion-Molinier have approved the appointment, at the suggestion of Air France President Max Hymans, of Louis Lesieux as Managing Director of the company. Now in his 48th year, Lesieux made his name in the expansion of Orly Airport. In 1948 he was appointed Managing Director of Paris Airport, a post which he has retained until now. In his new position he will be aided by Maurice Lemoine as Secretary General and by the two newly-appointed Assistant Managing Directors Raymond Dupré (hitherto Technical Director) and Robert Montarnal (hitherto Financial Director). New Financial Director is Emile Delclaux. - The retiring Managing Director René Briend has been given the title of Honorary Managing Director; he will continue to act in an advisory capacity.

INTERNATIONAL METEOROLOGICAL CONGRESS

The Second International Congress of the World Meteorological Organization, a body affiliated to the United Nations, with 87 member States, is meeting in Geneva. The agenda covers such subjects as methods of short, medium and long-range weather forecasting; effect on weather of extraneous causes, such as atomic energy; meteorological telecommunications etc. - In his opening speech W. M. O. Chairman Professor F.W. Reichelderfer (U.S.A.) described the tremendous progress that has been made in weather services since the old International Meteorological Organization was founded in 1878... which did not prevent Geneva from suffering from cold winds during the "weather makers" congress.

SCIENTIFIC CONSULTANT GROUP FOR CONVAIR

The Convair Division of General Dynamics Corp. has appointed a scientific consultant staff consisting of fourteen leading scientists from American research centres and universities. Members include Dr. Edward Teller (University of California) who played a leading part in the development of the hydrogen bomb, Dr. Robert F. Mehl (Carnegie Institute of Technology), Professor Theodore von Karman (Chairman of N.A.T.O.'s Advisory Group for Aeronautical Research and Development), Dr. Fred L. Whipple (Chairman of Harvard University's Department of Astronomy). The consulting group is to deal with the following questions: Special problems in the development of military aircraft and guided missiles, atomic research and industrial application of atomic energy (presumably in connection with the research contract for an atom-powered aircraft awarded Convair by the U. S. A. F.).

COMMERCIAL AIRCRAFT PRODUCTION FOR EAST GERMANY

The Government of the East German People's Republic plans shortly to take over the long-distance air services originating from East Germany which are at present operated by air lines from other east European countries, and to organize the production of commercial transports.

WORKSHOP BRIEFS...

Houdaille-Hershey Corp., of Detroit, Mich., and Gilfillan Bros., of Los Angeles, Calif., have signed an agreement giving Houdaille-Hershey sole production and sales rights for Gilfillan "Vari-Flow" high-pressure hydraulic pumps. * Two Solar T-41 gas turbines to produce additional electrical current have been fitted in the U.S. Air Force's C-131Bs which are being built by Convair as "flying electronic test beds". Ryan Aeronautical Co. is now offering its Firebee jet-powered target aircraft for tactical use; with appropriate equipment it could be used as guided missile or pilotless reconnaissance aircraft. * The Lockheed T2V-1 Navy jet trainer has been equipped with a boundary layer blower system. Air bled off from the jet is blown out over the landing flaps and ailerons, enabling the landing speed of this aircraft to be reduced to 97 m.p.h. * Bréguet 965 (predecessor to the Bréguet 1050 three-seat anti-submarine aircraft) has begun flight testing under Yves Brunaud. * Société Salmson announces development of two new engine types: Salmson 4 AH (100 h.p. flat-four) and Salmson 6 AH (145 h.p. flat-six). * More than 70 flights have so far been made by the English Electric P.1 fighter; supersonic speeds have been reached on most of them. * Projects for a VTO type and a convertible aircraft are in preparation at Hiller Helicopters. The firm is also working on a large transport helicopter. * Helicopter rotor blades with boundary layer control devices are being tested in a Piasecki H-21 helicopter. * The latest versions of the Pratt & Whitney J-57 jet engine deliver a take-off static thrust of 11,000 lbs. without thrust-increasing devices.

* * *

The Last Weapon but One

On February 17th, 1955, members of the Institute of the Aeronautical Sciences met in Los Angeles to discuss the latest generation of American fighters. Discussion centred round a report by Lockheed Test Pilot Anthony William ("Tony") LeVier on his flights in what was assumed to be the Lockheed F-104, which—to judge by the secrecy surrounding it—is probably the United States' most advanced fighter. Among other things he said: "Aero-elastic qualities of the new fighters can be spectacular, if not alarming: on the ground the structure looks as solid as can be desired, but at high speeds it flops around like a dishrag..."

His remarks sum up to the following: the latest jet fighters are neither particularly reliable nor easier to fly than their predecessors, and the recruitment of pilots is getting more and more difficult.—Many of his listeners may well have gained the impression of being told that they were designing the *last of their piloted fighters;* that the guided missile is just about to take over.

*

Interavia has discussed the subject of guided weapons on several occasions during the past few years. As chance would have it, an earlier rocket issue appeared exactly two years ago, in May 1953. Former President Truman was quoted as describing rockets as "fantastic weapons", and a military contributor used the expression "soulless weapon". Two years have since gone by, during which—as the present issue shows—fantasy has become reality, and "soullessness" has become more and more evident.

Both Eastern and Western giants are engaged feverishly in research and development of these weapons. What is happening in the Soviet Union can only be surmised. But what the United States is doing can be learned almost daily from information released to the public apparently not without special reasons.

For example, in his 1954 Report Admiral DeWitt C. Ramsey, President of the Aircraft Industries Association of America, writes: "...Important progress also has been made in *guided missile* development and production. Not only are 26 different models in project status in the aircraft industry, but such great emphasis is being placed on this type of armament that the *Department of Defense is spending as much on research and development in this field as in the field of piloted aircraft.*"—Incidentally it may be mentioned that two of A.I.A.'s nine technical committees deal exclusively with rockets and guided missiles, the Rocket Technical Committee and the Guided Missile Committee.

This planning by Defense Department and aircraft industry is illustrated even more graphically by a report from *Interavia's* West Coast representative: "...Los Angeles has long claimed the distinction of being the 'airplane capital' of the United States. Now, practically overnight it has become the hub of the nation's *rocket and missiles industry.* Today uncounted millions of dollars are being poured into major and component missiles production plants. There is hardly an aircraft plant in all the region that is not involved in the manufacture of military rockets, guided missiles, components or accessories. Universities, airframe companies and civil and Government laboratories dot the area in a profusion of concentrated basic and applied research covering missile structures, aerodynamics, guidance, rocket motors, fuels, ballistics and testing techniques. The three U.S. inter-continental missiles so far officially identified—Convair's *Atlas,* Northrop's *Snark* and North American's *Navaho*—had their creation here."

*

Why California? The beginnings could be traced back, as in every history of flight, to the Chinese, who set off the first rockets thousands of years ago. Or the work of the Peenemünde "magician's apprentices", who thought they could force Britain to her knees with the V.2 reprisal weapon, might be mentioned. But rocket research since the war has really been concentrated in the United States.

One of the pioneers was "lone wolf" experimenter Dr. Robert H. Goddard, who succeeded as long ago as 1935 in guiding a small rocket to a height of 7,500 ft. in New Mexico. The most decisive contribution, however, was made by Professor Theodore von Karman, who left his chair at Aachen in 1929 to head the Guggenheim Aeronautical Laboratory of the California Institute of Technology (GALCIT), Pasadena—also in the Los Angeles area. It would be going too far to enumerate all the disciples, now world-famous, whom he gathered around him for rocket research. Due credit must, however, be given to the great impetus which GALCIT gave to rocket research in the Western World. Karman was able to convince General H. H. Arnold, then Commanding General of U.S. Army Air Corps and its real father, that his theories were correct. Today, this rocket research has grown into a full-scale rocket industry.

*

Once again an old saying has been proved true: war is the father of many things. The closing months of World War II brought forth its "most remarkable and most controversial offspring," the space weapon and the atomic bomb. And in this age of technical and physical progress it is inevitable that these two offspring should have made their way. To ignore this fact would be more than a crime, it would be stupidity.

Military writers consider optimistically that this threat to the civilized world is also its protection, a guarantee that peace will be maintained: if one side decided to push the button launching the atomic long-range weapon, it would in fact be pushing two buttons at once, since the adversary would retaliate within minutes. May the military be right! It may be true that the general is loath to use the sword, knowing how sharp it is. But what about the leaders of nations who in certain circumstances might regard war as a continuation of their politics with other means?

A typical case is that of the former Commanding Officer of Germany's rocket centre at Peenemünde—today a scientific rocket expert in the United States and one of the writers in this issue—who in his article ignores the military use of long-range weapons and drafts a touristic idyll in place of death and destruction.

*

The Editors too would prefer to deal with peaceful subjects.

To begin a third world war with thermonuclear long-range weapons would mean setting off a "chain reaction" which would be bound to run completely wild. The rocket with an atomic warhead would in fact be the last weapon—bar one... the next and final weapon would surely be, as Einstein says, the stone-age club. *EEH*

The State of the Art

BY JAMES FENTON SMITH, LONDON

Rocketry is not a new art. It is, in fact, almost as old as gun powder itself.

Dr. Donald A. Quarles, U. S. Assistant Secretary of Defense for Research and Development, the scientist in overall charge of America's guided missile programme, on December 1st, 1954, recapitulated what had been achieved in this domain during World War II. "Both sides perfected free-flight rockets in the air-to-ground, air-to-air, ground-to-air and ground-to-ground categories", he said. "Also during World War II both Germans and Allies applied guidance to bomb-like and plane-like devices: our *Azon, Razon* and *Bat* weapons are illustrative, the German V.1 pulse-jet missile was even more ambitious. The Germans, however, went much further. Their V.2 missile, with its powerful liquid-fuel and oxidant motor, rates as one of the graet technical achievement of World War II...

"In short, we ended the war with rocketry revived and advanced in many forms, and above all with the conviction that such weapons would play a much more important role in any future war.

"What the Russians did from that point onward is enshrouded in the Iron Curtain. As far as we are concerned, a very comprehensive programme of guided missile research and development was laid down. To some extent the programmes of the three Services overlap, but some amount of duplication is wholesome. The sixty-four-dollar question is how much of it we can afford..."

How far has the U.S. missile programme progressed? This question was answered on January 11th by a top U.S. Defense Department official who said: "We are today at the pay-off stage in the state of development of the art which far exceeds anything that anyone has yet achieved." On the assumption, however, that the Russians—who have been engaged in missile development longer than the Americans—have reached a similar stage, this means that the U.S.A. and the Soviet Union are reaching a point where *in theory* the air defences of each country are *nearly* impenetrable, while each of them has the weapons necessary to attack the other... in other words, a stalemate."

From an industrial point of view, this "pay-off stage" means that missiles are becoming big business. In fiscal 1954 the U.S.A. spent about $634,000,000 on missile *procurement* (against $2,500,000,000 for aircraft procurement). In the current (1955) fiscal year, funds spent on missile development *and* procurement are estimated to reach $1,200,000,000, and this figure is expected to rise considerably in the 1956 fiscal year beginning next July 1st. There is no doubt that in the next few years aircraft production will taper off while missile manufacture will expand. On January 11th a U.S. Defense Department executive said: "Ten years from now we'll be spending billions annually on missile procurement..."

Missile Categories

Before dealing with missile problems in greater detail, it may be useful to list the basic categories and roles of the missiles now being produced or developed. Although it may be assumed that both the U.S.A. and the Soviet Union, and to a lesser extent also Britain, France and some of the smaller countries, are developing missiles in all or at least some of these categories, the case of the U.S.A. is illustrated below because more missile information has been released in that country than in any other. Indication of missile types does not mean that only one type is available in each category; furthermore, numerous sub-types and special missiles are in existence.

Background to today's missiles

Missiles produced in any *quantity* since 1945 mostly owe their existence to German research and experience. If the progress of missile development in Germany in the decade up to 1945, which culminated in the mass production and operational use of several types of unmanned weapons, is matched against the corresponding period since that date, however, a slightly false impression is gained. It is true that only recently have these weapons reappeared in operational service with the U.S. and Soviet forces, but the delay is entirely due to the problems of guidance, of which the Germans had barely scratched the surface.

Guidance, therefore, is one of the major stumbling blocks in missile development. Otherwise, although the guided weapons of today are infinitely more destructive in their nuclear potentiality than anything produced at Peenemünde, the rocket power plants which

Guided Missile Rôles

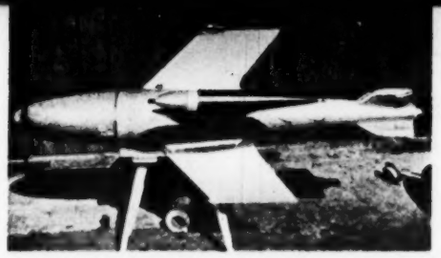
Missile Category	Army	Navy	Air Force
Surface-to-Air	Air defence of Continental U.S.A. and forward areas (e. g. *Nike*)	Air defence of the Fleet and Marine Corps land bases (e. g. *Terrier*)	Longer-range air defence of Continental U.S.A. (e. g. *Bomarc*)
Air-to-Air	–	Air defence of the Fleet (e. g. *Sparrow*)	Air defence of Continental U.S.A. (e. g. *Falcon*)
Air-to-Surface	–	Attack on Surface Targets (e. g. *Bullpup*)	Strategic air attack (e. g. *Rascal*)
Surface-to-Surface	Tactical support of ground forces (e. g. *Corporal*)	Ship-launched attacks on surface targets (e. g. *Regulus*)	Tactical air attack (e. g. *Matador*) Strategic air attack (e. g. *Atlas*)
Air-to-Underwater	–	Air attack on submarines (e. g. *Petrel*)	Air attack on submarines (?)
Underwater-to-Surface	–	Attack from submerged submarines on land or sea surface targets (?)	–

in the main provide their propulsion are in many cases straightforward developments of the remarkable technological advances of German scientists.

Both in Russia and the United States German experience has been used to such a degree that it embraces not only the weapons, but also the original design teams, who are continuing from where they left off in 1945. In the U.S., Dr. Wernher von Braun himself is working on V.2 developments, while Russia also received a batch of Peenemünde scientists, some 200 in number and including several top-rank technicians.

From what has been released on British activity, on the other hand, it would appear that German experience, if not ignored, has been largely abandoned for independent lines of research.

But in the race for a successful guidance system, which must be accurate, reliable, in spite of size limitations and accelerations involved, and capable of operating over ranges of perhaps several thousand miles, there is very little assistance to be gained from German experience. This amounted to no more than the use of transmissions along fine wires unwound from bobbins in the fins of the Ruhrstahl X-4 air-to-air missile, some basic experiments with ground electronic command, and of the inertial system of self-guidance with the V.2. One advantage of the inertial system, which makes use of integrated accelerometers indicating unscheduled forces to gyroscopes, which correct any deviation from course through servo-mechanismus acting on the control surfaces, is that it cannot be jammed. In its basic form, however, it renders the missile more open to interception, as it is travelling on a constant flight path.



Grandmother of modern guided missiles was the World War II Ruhrstahl X-4 air-to-air missile. Advanced versions are said to have been developed in the Soviet Union.

Guidance is the main problem

Electronics are the key to missile guidance, which varies for range and role. In the shortest ranges of operation, guidance may even be dispensed with. Basically, electronic systems may be divided into guidance and homing control, the former system usually involving some human agency, while generally speaking, homing missiles are automatic, having the power to "think".

Typical guidance systems include *beam-rider control,* principally for ground-to-air weapons, in which the missile intercepts and follows a narrow coded radio beam automatically locked on to the target by radar, and *command guidance,* also for surface-to-air weapons, where signals from one radar beam tracking the target and another, tracking the missile, are fed into a fire control computer which constantly plots interception data and transmits it in the form of command signals, to the missile for steering corrections. In the *plotted trajectory* system, ground radar is used to plot a surface-to-surface missile, and compare its trajectory with the predetermined flight path. A radar tracking beacon in the missile strengthens the signals received from the ground, before they are returned, while another rocket-borne electronic device translates ground commands into control surface corrections. The latter also shuts off the power of the missile at the appropriate point, to bring it down on to its target.

With all systems using radar, the waves of which travel in straight lines, some limitation on operating distance is imposed by the earth's curvature, but by increasing the height of the transmitter, in some cases by mounting it in an aircraft, the range may be greatly increased.

Homing devices may be classified as passive, active, or semi-active:

Passive homing is dependent on energy generated by the target, which may include heat, through the medium of infra-red rays, magnetic radiations from electronic equipment, or even electrostatic discharge caused through the passage of the enemy target through the air. Its disadvantages are that these manifestations are generally only discernible at short ranges, and also that jamming is fairly simple.

Active homing involves the installation of a complete radar installation in the missile, including a scanner aerial, transmitter and receiver, which is a formidable engineering problem, apart from being expensive and imposing a stiff performance penalty. A radar installation capable of being carried in a missile might also be fairly easily jammed.

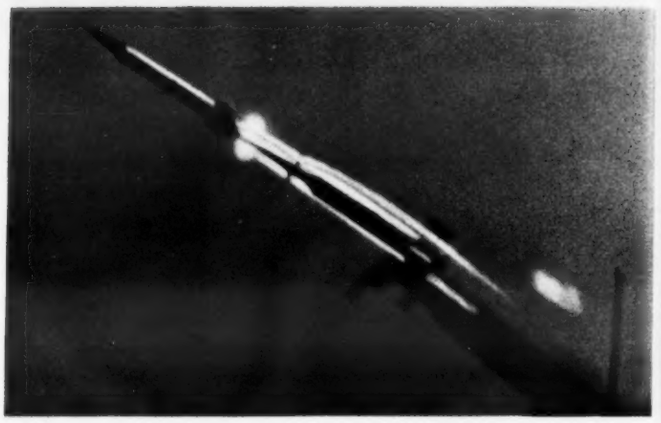
Semi-active homing is likely to be a more successful compromise, in that only a receiver is carried in the missile, the transmitter and scanner being either in an air or ground station and used to "illuminate" the target. Initially directed from the ground, the semi-active missile eventually picks up on its own receiver radar echoes from the target which is being tracked, and these are converted to the usual steering corrections, through servos.

Vast research projects are now being pursued, in the U.S. and U.S.S.R., to develop ultra-long-range strategic missiles known as ICBM (Inter-Continental Ballistic Missile); this type of missile follows a ballistic trajectory but in its final approach will be dependent on some form of guidance if any accuracy is to be achieved. The other long-range type of missile, which—having wings—follows a more horizontal cruise path and is similarly being developed for ranges of 5,000 miles, also requires extremely accurate flight control. For this sort of range, electronic guidance systems are per-

Hughes GAR-98 *Falcon* self-homing air-to-air missile of U.S.A.F. is said to be one of the most formidable weapons in the arsenal of the West. Weight, about 100 lbs.

Falcon tracks and hits four-engined target drone despite latter's violent evasive action.

One of the few British rockets to be disclosed is this old Armstrong-Whitworth test vehicle. Wrapped around it are eight boosters in pairs of two, which are explosively jettisoned after burn out.



Another British experimental rocket with a single booster motor is launched at the Ministry of Supply Trial Establishment at Aberporth, Cardiganshire, Wales.

haps less suitable than fully automatic homing, particularly as several homing systems are almost immune to enemy interference.

Among these is a development of the inertial system known as star-tracking, which is basically automatic celestial navigation. Star tracking requires a steady platform and a fixed velocity and is therefore confined to winged cruise missiles. One method involves the use of two tracking telescopes in the missile, aligned continually on one or more selected stars by means of photo-electric cells. This alignment controls the missile so that it follows the instantaneous sub-stellar point, which is the imaginary point on the earth's surface on a line from the centre of the earth to the star, tracing a curved path during the earth's rotation that can be used as an extremely accurate missile path.

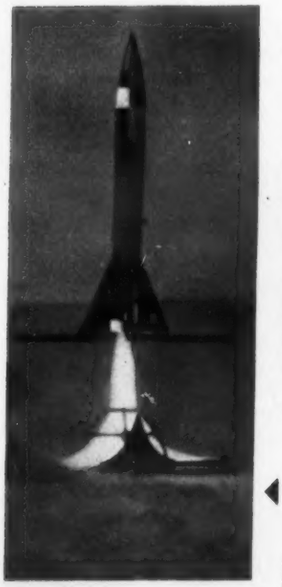
An alternative and equally accurate long-range guidance system is the hyperbolic approach, requiring several ground stations transmitting overlapping signals on the Loran or Decca principle.

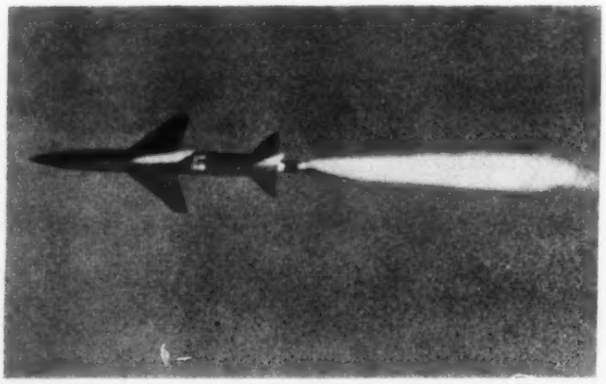
Missile Development

Although a high degree of secrecy attends all guided weapon development, it is known that the U.S., U.S.S.R. and Great Britain have ambitious research and production programmes, followed to a very much lesser degree, by Canada, France, Sweden and Switzerland, while even Norway has set aside the equivalent of $700,000 for the development of missiles for coastal defence. Dealing with the smaller programmes first, *Canada,* while also receiving guided weapons and design data from the United States, is continuing research into missiles for the R.C.A.F. The Canadian Defense Research Board successfully launched a "working model" of an air-to-air missile from a Canadair *Sabre* near Ottawa in August, 1953, and production versions of this AAM will eventually be carried by the Avro Canada CF-100, together with the Hughes GAR-98 *Falcon.*

Little information is available on *French projects,* but some idea of the trends may be gathered from the fact that among the technicians engaged on research for the *Armée de l'Air* for many years was Dr. Eugen Sänger, who is one of the principal pioneers of the ram-jet. One of the most significant of the French projects is the *Matra M.04,* which is described by its designers, S.N.C.A.S.E. and Société Matra, as a two-thirds scale model of a projected anti-aircraft weapon. With a 2,750 lb. S.E.P.R. liquid-rocket unit, the M.04 has reached 1,100 m.p.h. when released on tests in the Sahara from a *Halifax* at 13,000 ft. Further launchings have been made from beneath the wings of the *Grognard* experimental fighter.

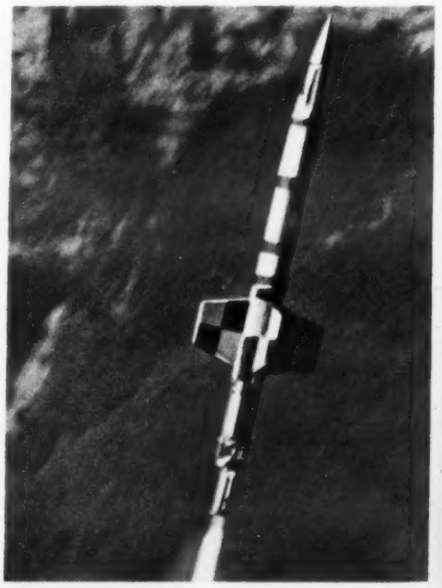
In addition to one or two small missile projects, such as the S.F.E.C.M.A.S. S.S. 10 anti-



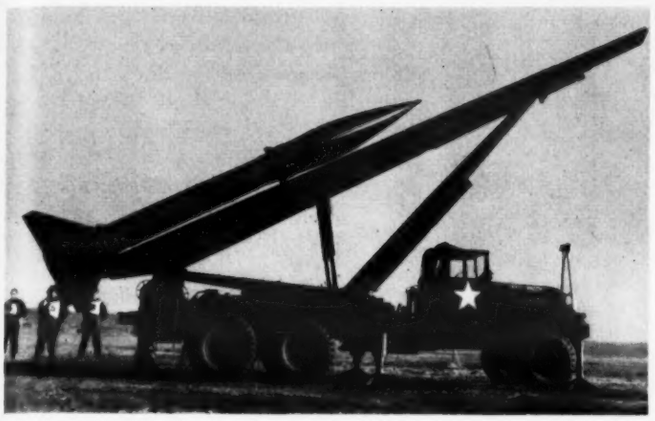


The *Matra M.04* experimental rocket, forerunner of a guided anti-aircraft missile.

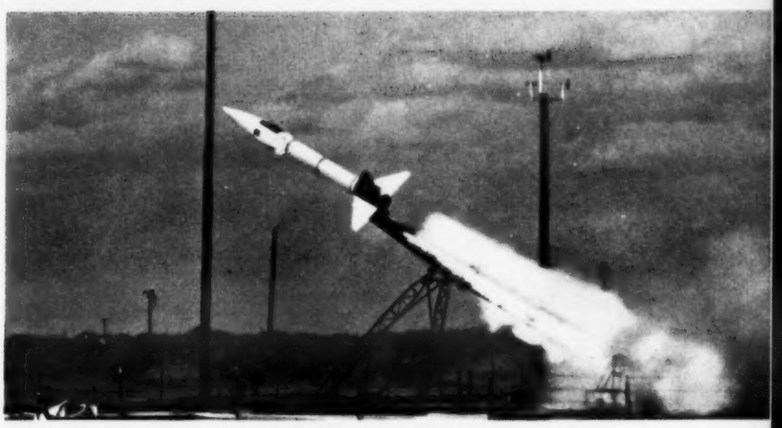
France's *Véronique* upper-air research rocket.



The Swiss Oerlikon beam-rider anti-aircraft rocket being test-fired somewhere in the Alps.



The Douglas *Honest John* 762-mm free-flight artillery rocket has been issued to U.S. troops in Germany.



Honest John being test-launched at White Sands Proving Ground, New Mexico.

tank rocket around which the Potez 75 light attack aircraft was designed, a further French design of interest is the *Véronique,* intended for upper air research up to 410,000 ft., and produced by the *Laboratoire de Recherches Balistiques et Aérodynamiques.* With a weight of 2,172 lb., the *Véronique* is launched without boosters from a simple platform, like the V.2, but to avoid the necessity for gyroscopically-controlled graphite control vanes, it is stabilised during its initial ascent by cables attached to outriggers on the fins. During trials, *Véronique* has reached a speed of 3,100 m.p.h., and an altitude of 40 miles, while with a military load, it would have a range of 150 miles. The former French Air Force Secretary, Diomède Catroux, recently indicated that a long-range surface-to-surface missile is being developed in France.

What is known of *British progress* in the missile field is described by *Interavia's* London Editor elsewhere in this issue.

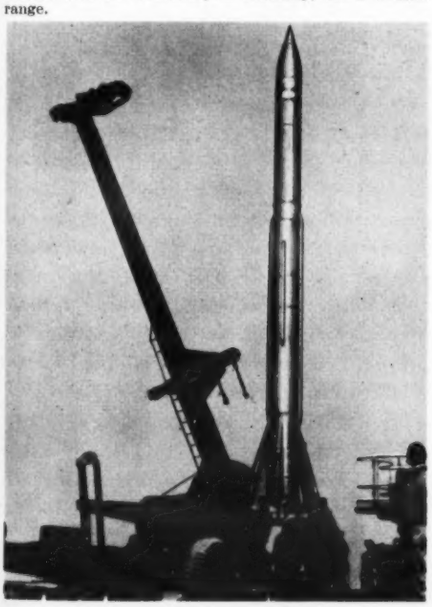
Perhaps the most startling report from Britain concerns the new radar chain covering the country, with hundreds of subterranean control units, and with new and more efficient types of radar linked with a further network of electronic instantaneous response controls. When perfected, these, it is hoped, will automatically scan all objects travelling in the air and with the aid of centrally based computers identify them as friend or foe. If identified as enemy, the computer will trip a switch setting off action pulses, and these in turn will fire the missiles closest to the target, within a fraction of a second.

In the reorganization of the *Swedish armed forces,* it is proposed that GMs should be introduced for air defence at high altitude, leaving fighters to cope with medium-level raiders, and to operate in support of the army and navy. It was thought unlikely that guided missiles would replace fighters in any field during the next ten years. Six different classes of guided missile have been mentioned for procurement, in Sweden, for air defence, air force attack, air-to-air use, two types for use against naval targets, and an army anti-tank missile.

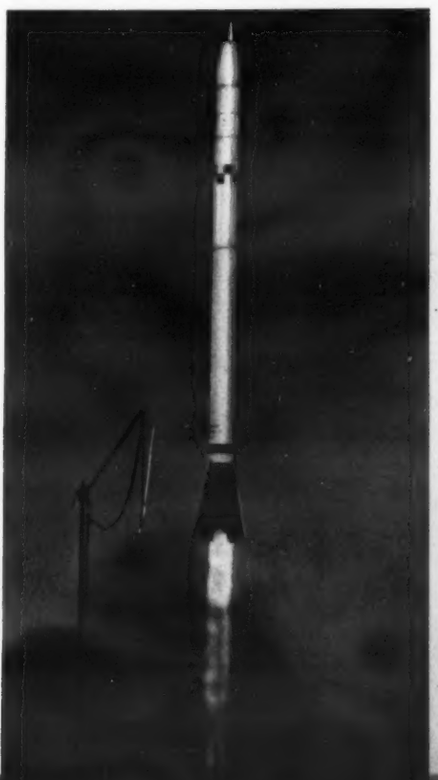
To deal with the new developments, a guided missile bureau, or *Robotvapenbyrån,* has been established, and the SAAB and Bofors companies are working on missile projects. The SAAB *Lansen* all-weather fighter will eventually be armed with AAMs.

In *Switzerland,* Oerlikon, Buehrle & Co., the well-known armament manufacturers, have entered the GM field, their first prototype being a 16-ft. anti-aircraft rocket with a liquid rocket motor giving a ceiling of 66,000 ft. With a launching weight of 550 lb., the rocket has a 44-lb. explosive warhead fitted with a proximity fuse and employs the beam-rider system of guidance. It features a mobile launcher and radar transmitter in two compact units, and it has

The Firestone *Corporal* tactical guided missile, also in service with the U.S. Army in Germany, has a 75-mile range.



Corporal takes off at White Sands.



Douglas *Nike* anti-aircraft guided missile after take-off. Ceiling is about 60,000 feet.

Douglas-Sperry-Raytheon *Sparrow* guided air-to-air missiles carried by a Douglas F3D *Skyknight* twin-jet night fighter.

attracted the interest of the U.S. Army, who have tested it under the designation MX-1868. During trials, the missile is recovered in two separate halves, which are lowered by parachute. Oerlikon is also making 8-cm unguided solid-fuel rockets for air-to-surface and air-to-air use.

With the largest and most expensive programme of development the *United States* has a total of six missiles in service, with a further two just emerging from the development stage and another score under construction. The weapons in operational service are with all three branches of the U.S. forces, and include the Firestone SSM-A-17 *Corporal,* which as its designation indicates, is a surface-to-surface missile for the Army, and the Douglas/Emerson *Honest John* 762-mm free-flight artillery rocket. Both these equip Army units in Europe, and can carry conventional or nuclear warheads, and while *Honest John* is unguided, *Corporal,* based on V.2 principles, has Gilfillan guidance and maintains itself on the axis of a radar beam until propulsion ceases at a predetermined acceleration, when it follows a ballistic trajectory at Mach 3. *Corporal* is reported to be extremely accurate over ranges of more than 75 miles, while *Honest John* reaches a range of only 20 miles.

First defensive surface-to-air missile to enter service with the U.S. Army, the Douglas/Western Electric SAM-A-7 *Nike* will equip more than 100 sites protecting 13 major U.S. cities. Claimed to be effective against aircraft flying up to about 60,000 ft., *Nike* also is a useful training missile since its command guidance applies to subsequent developments. *Nike* is steered by moveable nose vanes, actuated through servos from its radar receiver, and employs semi-active homing. *Nike* orders so far have totalled $200,000,000 which, at about $25,000 a missile, would be enough for 8,000 rounds. However, the contracts probably include money for research, development and manufacturing facilities. More than 1,000 *Nikes* had been produced by the end of 1952.

A controversy about the *Nike* broke out between the U.S.A.F. and the Army earlier this year when Air Force Secretary Harold E. Talbott intimated that this missile was capable of destroying only slow-flying piston-engined bombers. He was contradicted by Major General James H. Gavin, Army Assistant Chief of Staff for Operations, and as a result a test was organized in which a formation of jet fighter drones was fired on with *Nikes* without warheads. The results were not conclusive: the Air Force claimed that not a single drone was knocked down; the Army countered that not a single drone would have been left if the *Nikes* had been fitted with proximity fuses.—Meanwhile, a larger missile, the *Nike B,* is on its way, and recently it was confirmed that an atomic warhead is being developed for use against bomber formations flying at great height.

Convair SAM-N-7 *Terrier* guided surface-air missiles on twin launchers aboard the battleship U.S.S. *Mississippi.*

Fourth of the service missiles is the Convair SAM-N-7 *Terrier,* now being built in quantity for the Navy, which is a ship-launched beam rider utilising AN/SPQ-5 tracking and guidance radar, and AN/MSG-3 fire control. Its range is about 15 miles. Dual launchers are used to obtain a higher rate of fire. Two U.S. Navy heavy cruisers, the "Boston" and the "Canberra", will be commissioned this year as the first combatant guided-missile ships. The U.S. Marine Corps will be equipped with *Terriers* for the defence of shore installations, and the Army is also evaluating the missile. *Terrier* went into production in 1951, and nearly 1,500 have been built.

Complementary to *Terrier* is the U.S. Navy's AAM-N-2, 3 and 4 *Sparrow,* developed and produced jointly by Douglas, Sperry and Raytheon, for use by fleet fighters, which has been fired from Douglas F3D *Skyknights* in extensive test programmes. With solid-fuel propulsion it attains Mach 3 over a 4-to-8 mile range, and is a beam-rider with terminal homing. *Sparrow's* rôle is somewhat similar to that of the Hughes *Falcon,* discussed later. A further naval air-to-air missile now in production is the Philco *Sidewinder,* two versions of which are being built.

Completing the service missile picture is the Martin TM-61 *Matador* of the U.S.A.F., a turbine-powered (Allison J-33) tactical missile with a 550 mile range which equips two squadrons in Germany, with several more training in the U.S. Air Force missiles were formerly designated with the normal "F" and "B" numbers broadly indicating their function, in contrast with the Army and Navy missile tags which precisely define application, but with the dropping of the term "pilotless aircraft", operating units will be known as tactical, strategic or air defence missile squadrons or wings. *Matador* has therefore become the TM-61 (Tactical Missile), instead of the B-61, and there have been other changes.

Having trained on the B-61A as Pilotless Bomb Squadrons, the two tactical missile units in Germany are now equipped with TM-61Bs. These are ramp-launched horizontally from a mobile trailer by solid-fuel booster rockets and are radio guided from the ground. The

TM-61 dives supersonically on to its target from about 50,000 ft., and can carry an H.E. or atomic warhead. Its developments include the more powerful *Matador 2,* and the shorter *Matador 3,* which may be used as a surface-to-air missile. Cost of a *Matador* in quantity production is estimated at $90,000.

Present missiles are usually unable to operate further than 1,000 miles range, when rocket-propelled. Dominating the development programme, therefore, is the I.C.B.M. step-rocket project, for ranges up to 5,000 miles, carrying a nuclear warhead and costing more than the war-time Manhattan atom-bomb project ($2,000,000,000). The Convair SM-65 *Atlas* will be the biggest missile ever to be built, despite the fact that the reduction in size of the H-bomb has enabled its gross weight to be considerably lowered. The extent of the research programme connected with the I.C.B.M. may be measured from the fact that its speed is discussed in terms of Mach 15.0 or thereabouts—about 11,550 m.p.h. at sea level—and speeds up to Mach 20.0 are being investigated in a planned programme of hypersonic testing in the U.S.A.

A new 5,000 mile test range for the Inter-Continental Ballistic Missile, extending from Florida to the Ascension Islands, is being prepared, on which the officially announced aiming tolerance of 0.2 percent of range, or 10 miles after a flight over a 5,000 mile range, will be perfected. The trajectory for a 5,000 mile range rises to 800 miles above the earth, to which the second stage of the rocket will coast after burn-out at 22,000 ft./sec. The problem of guidance is complicated by the fact that as the rocket re-enters the atmosphere, air friction will build up heat sufficient to vaporize diamonds, which may consume the front part of the rocket, altering its aerodynamics and necessitating stowing the nuclear material and control system near the tail.

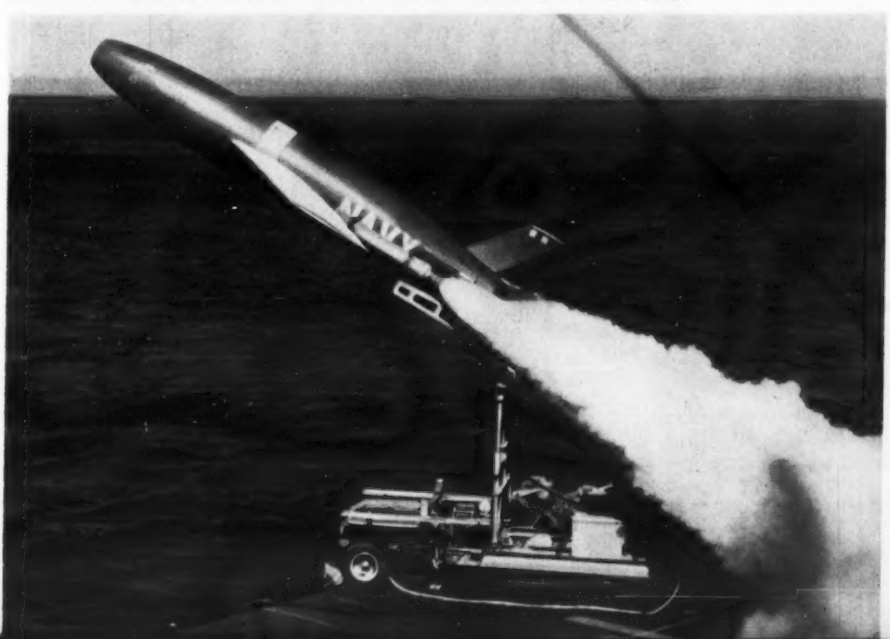
The missile range, stretching from the Banana River at Cocoa, Florida, site of Patrick Air Force Base, to the Ascension Islands is not yet ready for use. One reason is, as a Defense Department official said in January, that the U.S.A. does not yet have "the permission of all the people who own the real estate along the way. But we are assuming that we will get those permissions." As a result, the range is by no means instrumented yet. This has time, however, because construction of *Atlas* is in a very early stage. On February 25th General Nathan F. Twining, U.S.A.F. Chief of Staff, said construction work was "just getting going."

The first stage of the I.C.B.M. rocket will be powered by a North American unit delivering 120,000 lb. thrust, and requiring pumps for the liquid fuel of almost unheard-of delivery rates.

Terrier takes off from the *Mississippi*. The seagull looks scared.

An experimental naval surface-to-surface missile is the turbine-powered Chance-Vought XSSM-N-8 *Regulus*, here shown after take-off from aircraft carrier CVA-19 *Hancock*.

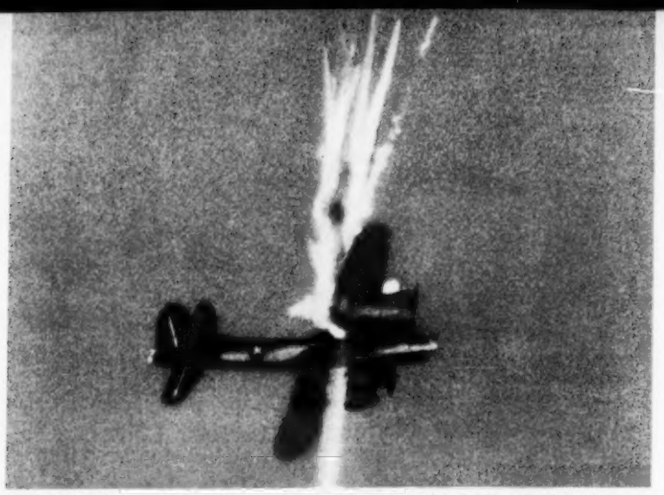
Regulus leaves launcher aboard aircraft carrier. Missile has folding wings for easy stowage.



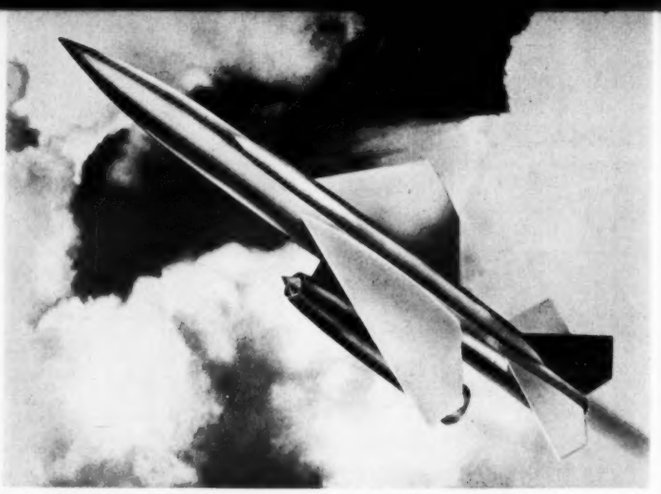
Maker	Year	Type	Use	Power plant
GREAT BRITAIN				
Armstrong Whitworth	1950	Canard	Research	—
Armstrong Whitworth/Sperry	1954	Navy anti-aircraft	Surface — air	—
Bristol	1950	JVT-1	Surface — air and research	2 ramjets + solid rocket
De Havilland	1954	—	Air — air	—
English Electric	1951	Anti-aircraft	Surface — air	Liquid rocket
Fairey/Royal Aircraft Establishment	1948	RTV-1	Surface — air	Liquid rocket
Fairey/Royal Aircraft Establishment	1947	Stooge	Surface — air	Solid rocket
Royal Aircraft Establishment	1945	Longshot LXCTV-2099	Research	Solid rocket
Royal Aircraft Establishment	1948	Lop-Gap	Surface — air and research	Liquid + solid rocket
FRANCE				
MATRA/SNCASE	1952	M. 04	Air — air	SEPR liquid rocket
SFECMAS/SNCAN	1948	Arsenal ARS. 5501	Target aircraft and research	Arsenal pulse-jet
SFECMAS/SNCAN	1952	S. S. 10 anti-tank rocket	Surface — surface and air — surface	Liquid rocket
SNCA du Sud-Est	1955	Model 1522	Air — surface	—
L.R.B.A. (Laboratoire de Recherches Balistiques et Aérodynamiques)	1950	Véronique	Surface — air	Liquid rocket
E.C.A. (Société d'Etudes et Constructions Aéronautiques)	—	ECA 20, ECA 26	Research	—
Etablissements Jean Turck	—	—	Research	—
ITALY				
Aurelio Robotti	1954	A. R. 4	Research etc.	Liquid rocket
SWITZERLAND				
Hispano Suiza (Suisse)	1954	8-cm shell	Air — air; air — surface and surface — surface	Solid rocket
Oerlikon	1949	8-cm shell	Air — air and air — surface	Solid rocket
Oerlikon	1950	Anti-aircraft	Surface — air	Liquid rocket
CANADA				
Defence Research Board	1953	Velvet Glove	Air — air	—
	1955	—	Surface — surface	—
U.S.A.				
Aerojet	1947	Aerobee	Research	Aerojet liquid rocket + solid rocket
Bell	1951	Meteor	Air — air	Marquardt ramjet
Bell	1953	GAM-63 Rascal (ex B-63)	Air — surface	Reaction Motors liquid rocket
Bendix	1949	Loki	Surface — air	Grand Central solid rocket
Bendix/McDonnell	1953	XSAM-N-6 Talos	Surface (Sea) — air	McDonnell ramjet + rocket
Boeing	1954	Triton	Surface — surface	—
Boeing	1952	IM-99 Bomarc	Surface — air	2 Marquardt ramjets + solid rocket
Chance Vought	1951	XSSM-N-8 Regulus	Surface — surface	Allison J-33-A-14 turbojet + boosters
Chance Vought/Eastman-Kodak	1953	XAUM-N-4 Dove	Air — submarine	—
Chrysler	1953	Redstone	Surface — surface	North American liquid rocket
Convair/Bendix	1951	SAM-N-7 Terrier	Surface — air	Aerojet liquid rocket + solid booster rocket
Convair	1955	SM-65 Atlas	Surface — surface	North American liquid rocket
Cornell Aeron. Laboratory	1953	Lacrosse	Surface — surface	Allison J-33-A turbojet
Douglas/Western Electric	1950	SAM-A-7 Nike 1	Surface — air	Liquid rocket + solid booster rocket
Douglas/Western Electric	1954/55	SAM-A-? Nike B	Surface — air	Liquid rocket + solid booster rocket
Douglas/Sperry	1951	AAM-N-2 Sparrow 1	Air — air	Solid rocket
Douglas/Sperry	1953	AAM-N-3 Sparrow 2	Air — air	Solid rocket
Douglas/Sperry (Raytheon)	1953	AAM-N-4 Sparrow 3	Air — air	Solid rocket
Douglas	1951	Corporal E	Surface — surface	Liquid rocket
Douglas/Emerson	1953	Honest John	Surface — surface	Hercules solid rocket
Fairchild	1949	SAM-N-2 Lark	Surface — air	Reaction Motors liquid rocket + 2 solid booster rockets
Fairchild/Nat. Bureau of Standards	1954	XAUM-N-2 Petrel	Air — submarine	Fairchild J-44 turbojet
Firestone	1953	SSM-A-17 Corporal	Surface — surface	Aerojet liquid rocket
General Electric	1949	Hermes A. 1/3	Surface — surface	General Electric liquid rocket
General Electric	1950	Hermes A. 2	Research	General Electric liquid rocket
General Electric	1951	Hermes B	Research	Ramjet
General Electric	1951	Hermes C. 1	Research	Liquid rocket
Douglas/General Electric	1949	Bumper	Research	Caltech liquid rocket
Grumman	1951	Rigel	Surface — surface	Marquardt ramjet
Grumman	1952	QF6F Hellcat	Surface — surface	P W R-2800
Hughes/Philco	1950	GAR-98 Falcon 1 (ex F-98)	Air — air	Solid rocket
Hughes/Philco	1954	Falcon 2 and 3	Air — air	—
Martin/Fairchild	1953	ASM-N-5 Gorgon 5	Air — surface	—
Martin	1953	AAM-N-4 Oriole	Air — air	Ramjet
Martin	1949	TM-61 A/B Matador (ex B-61)	Surface — surface	Allison J-33-A-37 turboprop + booster rocket
Martin/Philco	1954	XAAM-N-7 Sidewinder	Air — air	—
Martin	1946	RTV-N-12 Viking	Research	Reaction Motors liquid rocket
Martin	1954/55	ASM-N-7 Bullpup	Air — surface	—
North American	1948	Nativ	Research	Liquid rocket
North American	1954	SM-64 Navaho (ex B-64)	Surface — surface	Wright ramjets + solid booster rocket
Northrop	1950	SM-62 Snark (ex B-62)	Surface — surface	Allison J-71 turbojet
Raytheon	1954	XSAM Hawk	Surface — air	Liquid rocket
Ryan	1950	XAAM-N-1 Firebird	Air — air	Solid rocket
U.S.S.R.				
—	1945	C-2 Wasserfall	Surface — air	Liquid rocket
—	1945	Henschel Hs 117 Schmetterling	Surface — air	BMW/Walter liquid rocket + 2 boosters
—	1950	M-1	Research	Walter liquid rocket + 3 boosters
—	1950	M-100	Air — surface	Solid rocket
—	1952	M-103	Surface — surface	Liquid rocket
—	1945	Rheinmetall-Borsig Rheintochter R. 1/R. 3	Surface — air	Liquid + solid rocket
—	1945	Taifun	Surface — air	Liquid rocket
—	1945	V. 2-development	Surface — surface	Liquid rocket
JAPAN				
(University of Tokyo)	1954/55	Pencil	Research	Liquid rocket
(University of Tokyo)	1954/55	Baby	Research	Liquid rocket

GUIDED MISSILES

Thrust lbs.	Length ft. in.	Weight lbs.	Range miles	Speed Mach No. or m. p. h.	Ceiling ft.	Remarks
—	17′ 6″	—	—	—	—	Outboard auxiliary take-off rockets.
—	—	—	—	—	—	Tested at Aberporth and Woomera.
—	15′ 0″	—	—	Mach 2	—	Unguided experimental rocket; shown at Farnborough.
—	—	—	—	—	—	In production according to American reports.
—	—	—	—	2,000+	50,000+	Beam rider; wrapped boosters; nearing production.
1,000	—	800	—	2,000	—	Radio guidance test vehicle; parachute recovery.
300	7′ 5″	738	—	350	—	Command guidance.
—	—	—	—	—	—	Air to surface launched; shown at S.B.A.C. Display Farnborough.
1,000	14′ 0″	—	—	1,000	—	Radio guidance; shown at S.B.A.C. Display 1949.
2,760	15′ 1″	1,014	—	1,100	—	Experimental model (scale 2/3) for air-to-air rocket.
396	19′ 8″	1,450	200	300	app. 15,000+	Radio guidance over 30-35 miles; parachute recovery.
—	—	—	app. 2	—	—	Various applications; similar to Ruhrstahl X-4.
—	—	—	—	—	—	Under development; also version for air-to-air use.
8,820	19′ 7″	2,200	—	app. 3,100	400,000+	Research vehicle; cable-stabilized initially.
—	—	—	—	—	—	Build experimental guided missiles for testing guidance systems.
—	—	—	—	—	—	Development of guidance systems etc. for guided missiles.
—	—	—	—	—	—	—
1,200	3′ 7″	22	9	1,925	—	Unguided, approx. 2.2 lbs. warhead.
—	app. 3′	22	—	1,550	—	2.2 lbs. warhead; unguided.
—	16′ 6″	550	12	1,700	66,000	Beam rider; tested in U.S.A. as MX-1868.
—	—	—	—	—	—	In development for CF-100.
—	—	—	—	—	—	In development for Canadian Army.
—	20′ 0″	1,690	—	—	372,000	81 built for U.S.A.F.
—	—	500	—	Mach 3	—	Navy project.
—	20′ 0″	—	100	Mach 1.5+	—	Supersonic cruise; launched from B-52/B-48.
—	6′ 0″	—	—	—	—	Unguided; derived from German *Taifun*.
—	—	—	—	—	—	In production for U.S. Navy; launched from ships; *Talos*-W and *Talos*-L.
—	—	—	—	—	—	Experimental.
—	66′ 0″	8,500	250	Mach 2.5	60,000	Unmanned; carries GAR-98 *Falcon*.
5,000	33′ 0″	14,520	200	600	—	Training version under construction; with undercarriage.
—	—	—	—	—	—	In quantity production; heat seeker.
—	60′ 0″	—	100+	—	—	Derived from V-2.
—	14′ 8″	3,360	15	Mach 2	52,809	In operation; 1,000 in production.
120,000	—	—	Intercont.	Mach 15	3,000,000	Multi-stage rocket with hydrogen warhead.
4,600	—	10,000	app. 10	600	—	Built for U. S. Marine Corps.
—	20′ 0″	1,000	app. 20	Mach 2	60,000	Beam rider; more than 1,000 ordered, many in service.
—	25′	—	app. 40	—	—	Probably atomic warhead.
—	8′ 3″	280	app. 5	Mach 3	—	In production for U.S. Navy.
—	—	—	—	—	—	Under development.
—	—	—	—	—	—	Under development.
—	—	—	100	—	—	For U.S. Army; also *Corporal F*.
—	28′ 2″	6,000	20	Mach 1.5	—	For U.S. Army; unguided artillery rocket.
620	14′ 5″	1,210	10	Mach 0.9	—	Navy research missile; programme suspended.
1,000	—	1,500	—	Mach 0.7	—	For anti-submarine duties; launched from helicopters.
20,000	40′ 0″	12,000	150	Mach 3	270,000	For U.S. Army; H.E. or atomic warhead.
8,000	25′ 0″	12,000	50	Mach 2	100,000	U.S. Army; developed from *Wasserfall*.
25,000	—	25,000	300	—	—	Larger version of A. 1.
—	—	—	—	Mach 1+	—	U.S. Army project.
—	—	—	Intercont. ?	Mach 5?	—	U.S. Army project; multi-stage.
—	62′ 0″	26,895	—	3,500	1,158,400	V. 2 + *WAC Corporal*; max. altitude, programme cancelled.
—	—	—	—	—	—	Navy project; abandoned.
2,000	33′ 3″	11,380	1,800	375	38,500	Unmanned, radar-controlled *Hellcat* with warhead.
—	6′ 0″	108	—	Mach 3	—	In production for U.S.A.F.; for DF-89, DF-94 and DF-102.
—	—	—	—	Mach 3	—	Different guidance system from *Falcon 1*.
—	—	—	—	—	—	Navy development; shear wing; cancelled.
—	—	1,500	—	Mach 2	—	Navy project; development stopped in 1954.
7,000	39′ 5″	12,000	550	app. 620	45,000	U.S.A.F.'s first tactical guided missile in service.
—	—	—	—	—	—	Navy development and production.
20,000	42′ or 49′	15,000	—	4,300	834,340′	Fourteen *Vikings* built; derived from V. 2.
—	—	—	—	—	—	Under development.
—	14′ 6″	1,237	—	—	52,800	Project completed.
10,000+	—	—	Intercont.	Mach 2.5+	100,000	For U.S.A.F., cruising speed over Mach 1.
9,600	32′ 0″	14,000	1,000+	660	—	Tailless, supersonic cruise missile for U.S.A.F.; star tracker.
—	—	—	50	—	—	Anti-aircraft missile for relatively low altitudes; U.S. Army.
—	7′ 6″	600	—	—	—	Early air-to-air missile for U.S.A.F. and Navy; programme completed.
17,500	25′ 7″	7,800	app. 20	1,750	60,000	Derived from German A.5/A. 7; beam rider.
800+	13′ 0″	1,000	15	700	30,000+	Apparently used by Army and Navy.
3,000+	13′ 0″	3,300	—	Mach 1.3	—	Research missile, developed at Podberesye.
3,400	—	990	—	Mach 1.3	—	For aerodynamic research.
—	65′ 0″	100,000	1,850	—	—	Two-stage missile; allegedly derived from German A. 9.
app. 8,000	18.5′ or 15.5′	app. 3,800	12	app. 750	50,000+	Command guidance; improved versions tested.
2,200	6′ 0″	110	7.5	app. 1,850	50,000	Developed from German type; by Army and Navy.
—	—	30,000	200	3,500	—	In service.
—	—	—	—	Mach 2	—	Experiments only; no military use.
—	—	—	—	Mach 2	—	Purely experimental; high-altitude research.



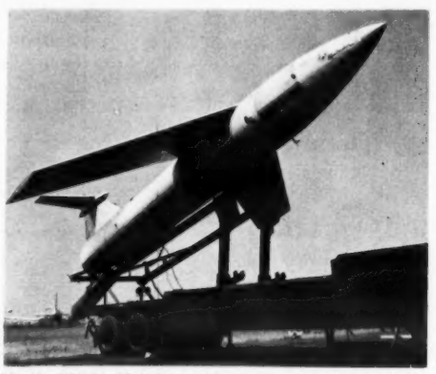
A GAR-98 *Falcon* guided air-to-air missile, without a warhead, hits QB-17 drone bomber, passes through aircraft amidships and comes out on top. Crippled drone crashed.



Boeing IM-99 *Bomarc* long-range interceptor missile will probably be armed with *Falcons*, will be retrieved by parachutes after completing its mission.

Trevor Gardner, U.S.A.F. Assistant Secretary for Research and Development, reported on March 15th that *Atlas*' motors will "develop millions of horsepower within seconds" of take-off. Nearer to completion than *Atlas* in the strategic missile category is the Northrop SM-62 *Snark* pilotless bomber. Formerly the B-62, *Snark* is a cruise missile of high subsonic speed, with a range of several thousand miles, achieved through the use of a turbojet, with a flush ventral intake. Initially fitted with a "hot" Allison J-33 delivering about 7,000 lb. thrust, the SM-62A will later have something like the 10,000 lb. J-71, and is tailless, with very thin, highly-swept high aspect-ratio wings. *Snark* also uses star-tracking guidance. General Twining said on February 25th that *Snark* "is coming along fine and has already been tested." Further tests are scheduled for later along the new South Atlantic range.

The third strategic missile, is the North American SM-64 *Navaho,* now undergoing initial flight tests, which is a supersonic cruise missile with nuclear capacity, and an operating range of 4,000 miles. After launching, it is rocket-boosted to climb to more than 50,000 ft., and then continues on its two ram-jets up to 100,000 ft., at Mach 2.5. It dives in a long descent to its target at M=4.0. The *Navaho* project



Martin TM-61 *Matador* turbine-powered tactical missile is in service with U.S.A.F. in Germany.

includes the X-10 ram-jet research vehicle, flown for the first time last year at Edwards AFB, and N.A.A. activity on air-bearing gyros which, being almost frictionless, do not precess. *Navaho* will therefore probably use some form of celestial guidance, with little possibility of interception.

Of the many other weapons under development and listed in the accompanying table, it is not possible to discuss more than a few in the scope of this article. Some of the most important include the 3-to-5-mile range Hughes-Philco GAR-98 *Falcon* air-to-air missile, formerly the F-98 and now redesignated Guided Aircraft Rocket; and the one-time F-99 *Bomarc,* by Boeing, now the IM-99 (Interceptor Missile). The difference in their redesignations is interesting, and is because the Falcon is an AAM, while the Bomarc is a SAM. The 6ft. long *Falcon,* which is shortly to be carried operationally by the North American F-86D *Sabre,* Northrop F-89 *Scorpion,* Lockheed F-94C *Starfire* and Convair F-102, possibly also by later versions of the North American F-100 *Super Sabre* and by the Lockheed F-104, is in production at the Hughes plant at Tucson, Arizona, and has Hughes automatic tracking, while a new development is its installation on the *Bomarc* — a missile upon a missile.

In quantity production *Falcon* costs about $10,000. Two new versions, *Falcon II* and *Falcon III,* are under development for the U.S.A.F., probably with more accurate guidance, greater range and striking power.

With a length of 66 ft., and a weight of 8,500 lb., *Bomarc* is too large a surface-to-air missile to be expended on each mission, and its latest application places it, at Mach 2.5 under the urge of its two Marquardt ramjets, and by command guidance, in position for release of its GAR-98 *Falcons,* after which it will probably be retrieved by parachute. *Bomarc* has a reverse-raked delta wing, and is intended for long-range protective cover above the operating ceiling of *Nike* and Bendix-McDonnell *Talos* (SAM-N-6), another ship-borne beam rider (three versions of the latter are being built. U.S.A.F. will also evaluate them). Tests with *Bomarc* are officially said to have been "very encouraging" and the type has been approved for operational use. U.S.A.F. circles hail *Bomarc* as the real answer to the air defence problem, rather than such missiles as *Nike,* because its 250-mile operating radius and its high speed permit interception of enemy raiders long before they reach their target areas.

Of considerable interest is another U.S.A.F. missile, formerly the Bell B-63 *Rascal,* and now the GAM-63 (Guided Aircraft Missile). This is a rocket-powered strategic air-to-surface

A booster helps *Matador* on its way from "zero-length launcher" at the Air Force Missile Test Centre, Patrick A.F.B., Cocoa, Fla.

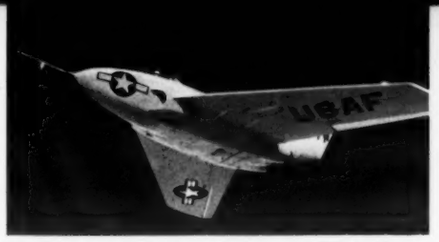
missile with a nuclear warhead, to be carried in the bomb bays of such aircraft as the Boeing B-52 *Stratofortress* and the supersonic Convair B-58 *Hustler,* and released many miles outside the main defensive system of the enemy at 50,000 ft. The GAM-63 then climbs to perhaps 100,000 ft., accelerating to Mach 2.5, guided by star tracking or inertial gyros, and either dives at Mach 3 on to its target, or releases another missile and returns to its base, airborne or ground. The GAM-63 has been developed from the Bell X-1.

Two further experimental rockets are the Chrysler *Redstone* ballistic rocket and the Bendix *Loki* barrage-type unguided anti-aircraft rocket. *Redstone* is intended as a longer-ranging successor to the *Corporal* tactical missile and will have double the latter's range, namely, 150 miles. Initial development at the Army's Redstone Arsenal, Huntsville, Alabama, aimed at a long-range strategic missile, but this was later dropped.—*Loki,* a small missile based on the German *Taifun* and powered with a Grand Central solid-propellant rocket, is reported to be in production.

Rounding off the American guided-missile picture are a number of naval weapons, including the Martin ASM-N-7 *Bullpup* air-to-surface missile under development and the Martin-Fairchild *Gorgon V* air-to-surface missile which was in production but has now been discontinued. Of particular interest are also the Fairchild AUM *Petrel* and Eastman-Kodak *Dove* air-to-underwater missiles which are dropped from aeroplanes or helicopters and "home" on submerged submarines.

The latest development announced in the United States is an underwater-to-surface guided missile with a thermo-nuclear warhead. Launched from submerged submarines lying off the coast of enemy territory, such missiles could well form a short-cut to the I.C.B.M.

This type is still very much in its infancy: American sources merely state that "research and development is in progress." However, it is conceivable that atomic submarines of the *Nautilus* type could serve as underwater-to-surface (or surface-to-surface) missile carriers. Furthermore, the Navy last March announced plans to build a giant, 4,600-ton atomic submarine at a cost of $95,000,000. Such vessels, experts say, could be used as missile carriers or, positioned off enemy coasts, could provide final target guidance to missiles fired several thousand miles away.



Precursor to a long-range guided missile? Northrop is developing the SM-62 *Snark* subsonic strategic missile, a tailless swept-wing pilotless bomber. Picture shows Northrop X-4 experimental aircraft.

Rheintochter III guided anti-aircraft missile of the German Army, now reported to be in use with Soviet forces in more advanced versions.

The *Russian* enigma certainly extends to missiles, although it is known that development of the German V-rockets began as early as August, 1945, in the Soviet-occupied Zone of Germany. Just over a year later, the main centre of development was shifted to the Soviet Union, the principal project being the M-103 two-stage long-range rocket. This had been started, from plans of the A-9 collected from Peenemünde, at Lehesten, in Eastern Germany, and was continued at Moscow-Chimki, and appears to be the first Soviet strategic missile. Its reported range is 1,850 miles, and its degree of development is unknown.

Apart from the M-103, the earliest guided missiles in Russia were entirely tactical, and included straightforward V.2 developments. It was not until 1949, when a special administration for rockets and V-weapons was set up in Moscow under the Ministry of War, with Alexander Yakovlev at its head, that a broader programme was planned. Although possessing very little experience of liquid rockets, the Russians had perhaps more of a head start than the U.S.A. in occupying the German army establishment at Peenemünde, the subterranean workshops for V-weapons in Thuringia, the rocket motor test site at Lehesten, and part of the Walter Raketentriebwerke in Prague, together with the testing site of the Peenemünde army establishment at Heidelager, in Poland.

Professor Artakianov organized the reconstruction of Peenemünde, and in a short time the largest testing site for V-missiles, the PVII, was operating again. The "Rabe" rocket institute began completing the projects interrupted by the Soviet break-through, and two special V.2 trains were also completed. In addition to V.2 type missiles, which are reported to have been produced in a dozen factories, with a total capacity of 2,000 missiles per month, surface-to-air anti-aircraft missiles are being produced in various plants at Kiev and Irkutsk. These SAMs include developments of the German Hs 117 and *Rheintochter* rockets, which are alleged to be in service with the Russian army, together with the C-2 *Wasserfall,* which was an efficient German design incorporating the first beam-rider guidance. Similar in many ways to a small-scale V.2, *Wasserfall* possessed exceptional stability, and was designed for altitudes of between three and nine miles penetration.

Batteries with these missiles were set up in September or October, 1952, in the air defence district of Moscow, and they are also located in the Baltic area and near Leningrad. An unguided German rocket, *Taifun,* which is also being built in the United States as *Loki,* is in service with Soviet units, ashore as well as afloat, where it is used for the defence of the 35,000 ton aircraft carrier *Sovetsky,* and the 40,000 ton battleships of the *Sovetoki Soyuz* class.

The M-1 and M-100 missiles are not considered significant, being in the same category as the British *Lop-gap* and *Longshot* experimental types. On the other hand the Russians, too, are reported to have developed an underwater-to-surface rocket with a range of 140 miles.

Guided-missile carrier, or long-range missile-guidance vessel? The U.S. Navy's first atomic-powered submarine SS-571 *Nautilus.*

Long-Range Missiles will make Peace Unavoidable

BY INTERAVIA STUDY GROUP

I. The military aspect

By "pushing the button", any aggressor would also blow up his own house

It flies half way round the world in less than an hour, crosses the oceans in a few minutes, ascends into the ionosphere and then plunges back into the earth's atmosphere, jettisons several casings successively before frictional heating melts them, and finally comes down and hits the earth with a thermonuclear sledgehammer—such are the main features of the intercontinental missile on which designers in more than one country are working.

Engineers see in it the evidence of a great scientific success, and strategists regard it as the supreme weapon. The complexity of the technical problems involved in its realization still further increases the power which military staffs attribute to the Inter-Continental Ballistic Missile (I.C.B.M.). All seem to consider that the first nation to possess a substantial stock of I.C.B.M.s would become the master of the world. In their imaginations they visualize such a scene as the following.

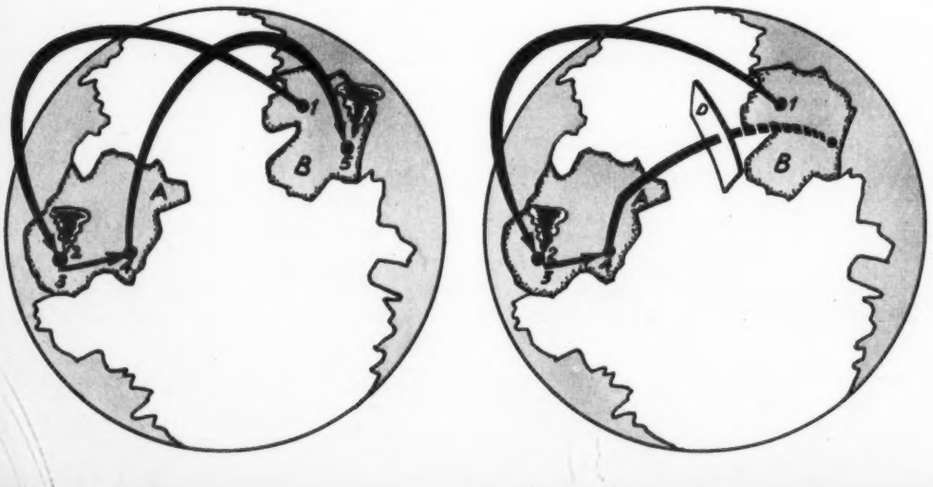
The military leaders of country A have built up reserves of long-range missiles. They know they have a considerable lead in this field. In agreement with their government they invite the military chiefs of country B, against which they have been waging cold—or even lukewarm—war for thirty years, to witness the launching of one of these missiles. The "enemy" accepts the invitation. In an operations room, whose most striking feature is a television screen occupying the largest wall, country A's chief of staff asks his colleague from country B to select a target from a number of desert islands several thousands of miles away, chosen to form the guinea pigs of the demonstration. He makes his choice, and the missile is launched. The two military staffs watch its departure on the screen. Then tea and cakes are served to while away the 34 minutes of its trajectory. A few moments before the time calculated for the destruction of the target, the island appears on the television screen. Palm trees wave in the breeze, the sea comes rolling gently on to the beach. The screen recalls the illustrations of the romantic literature which so charmed the sensibilities of the late 18th Century. Suddenly a great spout of earth and water replaces the peaceful scene of a moment before. The island has disappeared. The representatives of country B get up and group together in consultation. After a brief deliberation they announce their country's "capitulation". This is how, it is said, certain conflicts took place in China. The opposing generals met before the "battle", compared their strengths and their relative positions and decided on the winner without fighting. However sensible and attractive this way of settling differences between countries may appear, it is doubtful whether the intercontinental missile will bring us back to it.

This means of forcing a decision at a distance will perhaps be in existence in ten years. In the art of war it will mark the end of fifty years of precipitate evolution, the main outlines of which can be resumed as follows:

1.—During World War I fire power was superior to speed of movement. Though at times tremendous, with vast concentrations of artillery, this fire power was scarcely mobile. It moved at 3 m.p.h. and took a very long time to manhandle into firing position. The enemy meanwhile had time to organize his defence, and in the end the defensive won over the offensive.

2.—Twenty-five years later Hitler launched his "Blitzkrieg". He had retained the old fire power on the same scale but added speed to it. His tanks swept forward, preceded by Stukas to crush centres of resistance. The destructiveness of his fire power was increased tenfold by the speed of movement. The offensive triumphed.

If country B is the aggressor it launches its missiles (time 1). Their arrival (time 2) automatically sets off reprisals and the launching of country A's missiles (time 4). Country B receives them (time 5) a few hours after launching its own. All it has gained is a brief respite in destruction.
The previous cycle can be broken. If country A has no similar reprisal weapons there is no "round-trip" (and there would probably be no single trip either, as the simple threat would suffice to make A capitulate).
If country A had an efficient defence there would be only a "half-way trip". Knowing this, country B would not undertake an operation so dangerous to itself. Finally, if country B has a 90 % or 100 % certain defence, the cycle is interrupted, and B wins. But will the offensive missile be perfected before or after its defensive counterpart?



3.—Hiroshima introduced a new combination between fire power and mobility. This time the carrier was combined with the omnipotence of the explosive. During World War II the explosive had remained very similar to what it had been twenty-five years earlier, and added power of destruction had been obtained by using the maximum number of carriers, whether armoured divisions or air fleets. Each carrier had a limited power of destruction, but the enemy was worn down by their cumulative effect. Since Hiroshima the increase in unit destructive power has reduced the need for accumulation. Fire power is again superior to its vehicle, which has progressed less far than its explosive. The offensive would seem to be stronger in the air, but ground defence is possible. Defence is powerless against the former, while, returning to the combat conditions of 1914-18, a form of ground defensive appears effective in the atomic age.

4.—The inter-continental ballistic missile will provide the destructive power of a thermonuclear warhead with a vehicle worthy of its effects. This time, the offensive appears as the victor in all domains, or rather a "surprise" aggression which would rain down atomic fire-balls on the enemy's territory. For so far no means of defence is known against such attacks.

A two-way button

Actually the situation would be no different. For the inter-continental ballistic missile to become the instrument of world domination several conditions would have to be fulfilled.

On the moral level, responsibility would first have to be accepted for annihilating part of the earth and its inhabitants. The consequences would be serious enough for countries to continue to seek to settle their graver differences by localized conflicts fought out with conventional weapons.

On the military level, the experts in the aggressor country would have to be able to reply in the affirmative to the following question: Can we be sure that the enemy has no equivalent weapons?

For if both sides were more or less equally equipped it is obvious that push-button war would be a two-way affair. The first button would send off inter-continental nuclear missiles, but their arrival at their destination would in turn release the reprisal missiles. Destroying all the enemy's large towns would not prevent him from retaliating and wiping out the aggressor's cities. Within a few hours the damage caused on both sides could be on the same scale. Barring an attack of insanity—which would have to affect all the leaders of a country—such an operation would seem to be, to say the least, improbable, as it would be militarily stupid.

To make sure that the "atomic boomerang" does not come back on to his own head, the aggressor would have to be certain of several points.

First that he had a monopoly. But how could he be sure of having such a technical monopoly? The risk would be so great that he would need to be as well acquainted with the enemy's arsenal as with his own.

Then there is the question of defence. If the aggressor is sure of being able to stop the boomerang before it reaches his own country, then the operation would become rationally possible and militarily worth-while.

It may be that one day the defender will be able to launch other missiles against the attacking inter-continental missiles, destroying them in their passage through the ionosphere. The battle will then be fought out several hundred miles above the earth. Attackers and defenders will read their fate from the sudden appearance of flashes briefly lighting up in space. But we have not reached that point yet. Technical evolution suggests that the offensive missile will be ready before any defence against it is found.

There remains finally the possibility of finding a solution to the problem facing an aggressor who has decided to make use of his superiority in inter-continental weapons: that of destroying the enemy's reprisal missiles at their bases. If this were possible it would restore a virtual monopoly and remove the necessity for trying to intercept the reprisal missiles en route. The aggressor would have to concentrate the essential part of his resources on this task, since if his operation succeeded it would decide the outcome of the conflict. Deprived of its means of retaliation, the country so attacked would immediately have to ask for terms. Thus, just as in the age of the aircraft-atomic bomb combination, the destruction of the enemy's means of retaliation will remain the essential or even the sole objective of the initial attack.

With one difference, however. The operation is difficult enough today and may well become impossible when the inter-continental vehicle ceases to be an aircraft and becomes a missile. The inter-continental missile is much less vulnerable on the ground than the bomber. Both the missile and its platform, or launching ramp, can be mobile, dispersed and above all buried underground. Moreover its small dimensions make it a very difficult target to locate, even if the atomic warhead of the missiles used against it allows for a wide margin of error.

This brings out one of the peculiarities of the inter-continental missile project. Such a missile will inevitably be designed and produced in quantity. Neither of the two major powers can afford to allow the other a monopoly, even if the Iron Curtain on the one hand and the F.B.I. on the other are sufficiently impenetrable or efficient to leave the world in doubt as to the actual existence of the weapon. But when each has a stock of thermonuclear inter-continental missiles, whether simultaneously or with a certain time lag, they will not necessarily use them. Even if moral considerations do not restrain them, there will always be the boomerang effect mentioned above; this can only be overcome by the interception and destruction in "flight" of the reprisal missiles launched by the victim of an aggression.

The problem of intercepting a ballistic missile travelling at 15 to 20 times the speed of sound is no easy one. A mere few "misses" would lead to tremendous destruction. With the means at its disposal today, the defence estimates that it could scarcely intercept more than 10 to 15 % of an attacking force of strategic bombers. To raise this percentage to 80 or 90 % it needs interceptor missiles. If, in turn, the offense uses supersonic missiles, will it be possible to obtain a high percentage of interceptions? In time perhaps; but there would be a long period during which the offensive would be stronger than the defensive and hence during which an aggressor would push two buttons at once, his own and that of a reprisal which he would be powerless to halt.

II. The technical aspect

Inter-Continental Ballistic Missiles

I.C.B.M. is the abbreviation for Inter-Continental Ballistic Missile. Such rockets could also be called "inter-continental ballistic mass destruction devices", since—at any rate today—there can be no question of accurately aimed operations with this weapon against the enemy's forces, military installations or arms plants. Just because the I.C.B.M., on its elliptical flight path, can "stray" dozens, perhaps hundreds of miles, it is to be fitted—to make up for its lack of precision—with a hydrogen warhead . . .

Behind the project is the fear of blackmail by the threat of a terror that could only be prevented or repaid by counter-terror. All this sounds somewhat familiar to Europeans, with their experience of "reprisal weapons" in World War II . . . At any rate American apprehension about the Russians' development of long-range rockets and atomic projectiles has become increasingly marked in recent months and has led to widespread demand for an American I.C.B.M. On this point it is useful to read what Senator Stuart W. Symington, former Secretary of the U.S. Air Force, said in a speech in the Senate on July 21st, 1954:

". . . The incredible destructive power of hydrogen warheads makes it possible to destroy a nation by launching a hail of ballistic missiles against it . . . The elaborate and expensive systems of radar defence we are being urged to build would be utterly useless against such a missile barrage. Practical prototypes of these weapons already exist. But no workable method of intercepting or deflecting them has been devised, even in theory. There is no doubt that inter-continental ballistic missiles will be produced in quantity years before any adequate defence against them is worked out.

"Will the Communists have such I.C.B.M.s before we do? There are many reasons to believe they will. For over thirty years the Russians have been working on rockets—and this type of missile is a logical development of the twin-stage rocket. For some time now such Moscow papers as Izvestia, along with the East German press and radio, have openly announced their progress with twin-stage rockets. We know that over nine years ago the Russians captured a number of scientists who, in addition to working successfully on the V.2, were also designing an I.C.B.M. for attack on the United States. We can be very sure that these Germans, along with outstanding Soviet scientists—including the great atomic scientist Capitza—have made much progress in the latter field. We also know that over the years we have consistently underrated the ability of the Communists to manufacture superlative new weapons of war in large quantities. What better illustration of this ability could be given than the MiG-15 fighter? . . ."

Senator Symington continued:—"America has also made progress. But over here our policy is a far cry from the all-out programme of the Communists.

"The two all-important facts—the hydrogen bomb and the Inter-Continental Ballistic Missile—are not something in the distant future, to be handled by our children or our grandchildren. They are with us now, and they will be with us in great quantity within five to ten years . . . And on the basis of our present plans and programmes it is probable that the Communists will have these hydrogen missiles in large quantity before the United States . . ."

Nevertheless something also seems to be going on in the United States in the inter-continental ballistic missile field. To begin with, a series of captured German V.2 "reprisal weapons" (diameter 5 ft. 6 ins.; length 46 ft.) were launched at White Sands Proving Ground during the early post-war years: their maximum altitude was 115 miles, and their range about 180 miles.—As early as 1945 *Convair* received a contract from the U.S.A.F. for research and develop-

A series of captured German V.2s was fired soon after the war at the U.S.A.'s White Sands Proving Ground. Maximum altitude reached was 115 miles.

During roughly the same period three experimental ascents were made by the U.S. Air Force's Convair MX 774 research rockets at White Sands, when altitudes of more than 100 miles were obtained.

So far eleven out of a projected twelve Glenn L. Martin *Viking* research rockets (for the U.S. Navy) have been launched into the ionosphere. No. 11 (picture) rose to 158 miles.

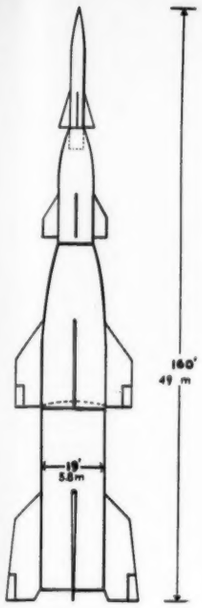


FIG. 1

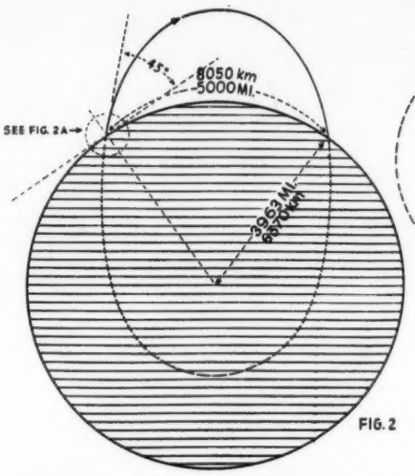


FIG. 2

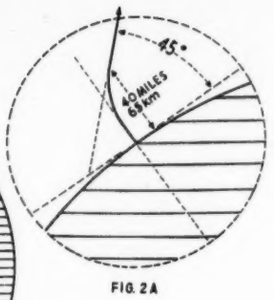


FIG. 2A

Left, drawing of a four-stage I.C.B.M.: length 160 ft.; gross weight 960,000 lbs. (for a 2,000-lb. warhead and range of 5,000 miles). Right, diagram of the elliptical flight path and the ascent path of this rocket; angle of elevation is 45°, burn-out velocity 7,300 m/sec or 14,200 knots.

ment of long-range ballistic rockets. They brought out an experimental rocket, designated the MX 774, of which three were built and launched. All three ascents were successful, and the greatest altitude reached was more than 100 miles. Although this rocket used the same propellants as the V.2 (liquid oxygen and alcohol), it was not a copy of the German space weapon, but a new independent and smaller design: diameter 30 ins., length 32 feet. [1]

Another research rocket, the *Glenn L. Martin Viking* built for the U.S. Navy, has so far been launched in eleven versions: *Viking No. 7* reached an altitude of 135 miles on August 7th, 1951; *Viking No. 11* even climbed to 158 miles on May 24th, 1954. Load of scientific equipment was over 400 lbs. in the first case and 500 lbs. in the second; launching weight was more than 11,000 lbs.; diameter 45 ins., length 50 ft.—Encouraged by these experimental launchings and the success of preliminary tests with a number of guidance systems for controlling rockets during their climb, the U.S. Air Force finally sponsored the Convair *Atlas* programme about which very little has become known.

As regards the *launching technique* for long-range ballistic rockets, it has long been known that the normal ballistic trajectory is not a parabola but an ellipse with the centre of the earth as one focus. To guide the missile to a given spot on the earth, this ellipse must be so chosen that it intersects the great circle of the "line of sight" at the target (cf.fig. 2, diagram of space trajectory).

The shape of the flight path depends on the velocity and height of the rocket at "Brennschluss" or "burn-out", i. e., when the rocket engine is shut off, as well as on the *angle of elevation* (angle between the velocity vector and a tangent to the earth below the point of burn-out; cf. fig. 2A). If velocity at burn-out altitude is *smaller* than the orbital velocity for this altitude[2] the flight path is an ellipse, with its *remotest* focus at the centre of the earth. If velocity is greater than the orbital velocity but smaller than the "escape velocity",[3] the ellipse changes its foci, i. e., the centre of the earth becomes the nearer focus. In the first case the rocket *must* return to the earth, in the second it *may* do so if the angle of elevation exceeds a certain value. Otherwise it would orbit the earth on an elliptical path (like the moon) and become a satellite. Only if the angle of elevation at burn-out were zero and the burn-out velocity were exactly equal to the orbital velocity would the flight path become circular.

This means that in practice ballistic rockets can be guided from the ground only during their powered ascent, not during travel on their free trajectory. The guidance system merely steers the rocket on a beam, with constant control of its velocity, to the optimum point for beginning the ballistic flight path. The Americans call this guidance system the "rubber gun barrel". Radar equipment on the ground ensures constant control of the rocket's direction and velocity, while automatic or remote steering systems (ground-to-air) act on the rocket nozzles and aerodynamic guide vanes, and keep the projectile in the "barrel" of the "rubber gun". When the predetermined values for velocity and direction are reached, the cut-off signal is radioed to the rocket, cutting off the fuel. In the event of faults, a "self-destruction" signal can be given.

Admittedly precision depends not only on accurate maintenance of the required launching values, but also on the behaviour of the rocket during return to earth and re-entry into denser layers of the atmosphere. German rocket engineers once proposed that space weapons should be fitted with small stub wings to extend the path of descent by a sort of "bounce and skip effect", but this method has been ruled out in the United States because of its lack of precision.

Whether future I.C.B.M.s are built as two-stage, three-stage or even four-stage rockets will depend solely on the propellants used, in particular on their specific impulse (thrust produced in relation to consumption) and specific weights (propellant weight per unit volume). Even if no further improvement could be made in specific impulse compared with that of the V.2, MX 774 or *Viking*, or in structural efficiency, a four-stage rocket built on conventional principles could still have a range of more than 5,000 miles and thus be classed as an I.C.B.M. For a warhead of 2,000 lbs. and a burn-out velocity of 7,300 m/sec (14,200 knots), the gross weight of all four stages would, however, be around 960,000 lbs. The angle of elevation of such a space weapon to ensure a range of 5,000 miles would be about 45°.

However, the "tug-of-war" between "atmospheric" and "extra-atmospheric" long-range weapon projects is still in progress. With the powerful turbojets and ramjets now available pilotless supersonic bombers for long ranges are already possible. Unlike the I.C.B.M., these robot bombers could be guided right to their target by automatic celestial navigation equipment. As, however, they have to remain within the earth's atmosphere throughout flight on account of their engines, and as they could scarcely exceed four times the speed of sound, they could be detected by radar and would be vulnerable to fighters and anti-aircraft rockets.

Whether ultimately invulnerable but inaccurate I.C.B.M.s are developed or vulnerable but controllable supersonic robot bombers, or perhaps even both kinds of long-range weapons simultaneously . . . the United States' Atlantic proving ground for guided missiles is to be substantially enlarged: from Cape Canaveral on the southern tip of Florida it is to stretch to the British Ascension Islands, a total distance of roughly 5,000 miles.

[1] The Convair MX 774 was the work of rocket engineer Bossart and a team of guidance experts led by Dr. Breitwieser,

[2] Orbital velocity is calculated from the formula $vC = \sqrt{g_o \frac{R_o^2}{R_A}}$, where g_o is gravitational acceleration (9.81 m/sec²), R_o the radius of the earth (6,370,000 m), and R_A the distance from the rocket to the centre of the earth. For a point 100 km above the earth's surface the orbital velocity (without allowance for air resistance) is 7,840 m/sec. or 15,200 knots.

[3] "Escape velocity" is determined by the formula $vP = \sqrt{\frac{2g_o \cdot R_o^2}{R_A}}$. It is thus always $\sqrt{2}$ times the orbital velocity. Thus for an altitude of 100 km it is 11,060 m/sec, or 21,500 knots. A rocket leaving the earth at this velocity travels on a parabola. If burn-out velocity is greater than vP, the flight path becomes a branch of a hyperbola.

"HUSH, It's Top Secret"

Britain and guided Missiles

BY INTERAVIA'S LONDON EDITOR

An early British test vehicle being launched at the Ministry of Supply experimental station at Aberporth, Wales, some time in 1950. The rocket was 20 feet long and 17 inches in diameter.

"Hush, its top secret". Those four words just about sum up the official British attitude regarding guided missiles. While the U.S.A. releases copious photographs and some data and proclaims its progress, the mere mention out of context of the magic words "guided missile" causes MI. 5 officials in Britain to don drab raincoats and depart for regions unknown, and opposition M.P.'s to table acid questions on security in the House of Commons. Public relations managers, on the other hand, wince every time a director after a good lunch starts off—"We are in the forefront of the guided weapons field . . ."

Through all this haze the poor unsuspecting air correspondent gropes his way trying to find out whether in fact Britain will ever have anything to fire at anyone, guided or unguided. His attention is usually discreetly turned to a variety of antiquated test vehicles which would not have interested German technicians in 1945 very much, let alone the world at large today.

The bald fact is that Britain has not yet reached the production stage with guided missiles (excepting one air-to-air missile of limited application). Major reason for the present non-existence of missile production lies in the complete lack of co-ordinated development after the war. Virtually nothing was done from 1945 to 1947, and even from 1947 to 1949 the only thing that was done was basic research at Government research establishments on fundamental problems. It was not until 1949 that long term development contracts were placed with industry, and here again these were limited in scope.

A little later a full programme was drawn up co-ordinating R.A.F., Army and Naval requirements. It was at this time that the planners suddenly realized that the missiles they had considered in the early post-war period were suitable only for dealing with subsonic jet aircraft and with piston-engined bombers flying at about 400 m.p.h. at 35,000 ft.

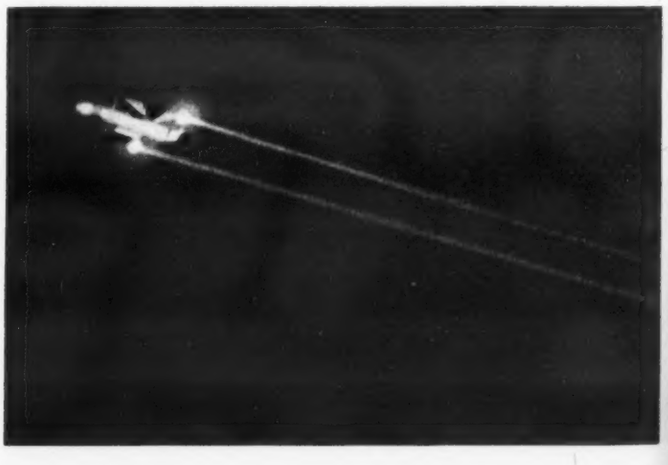
Hence it was decided to draw up long-term specifications for missiles in each major category and place contracts for a wide range of test vehicles in each, in addition to a range of fundamental research vehicles co-ordinated by such centres as the Weapons Establishment at Westcott and the Royal Aircraft Establishment.

Now, in 1955, the British missile programme is very extensive and is growing year by year. Over 150 firms are devoting their resources to some aspect of missile development and already over 1,500 test vehicles have been fired from the Long Range Weapons Establishment at Woomera, Australia and off the coast of Aberporth, Wales.

Operation of the weapons has involved development of entirely new systems of guidance differing in many respects from those employed in the U.S.A. Air defence missiles will be closely linked via electronic computers and controls with the vast new United Kingdom underground radar network. This, incidentally, is one of the basic differences between the American and British anti-aircraft defence systems, as the size of the American Continent makes impossible the close integration which can be achieved in the United Kingdom.

An English Electric ground-to-air missile test vehicle with four boost motors just falling away.

The same English Electric test vehicle proceeding under its own power.



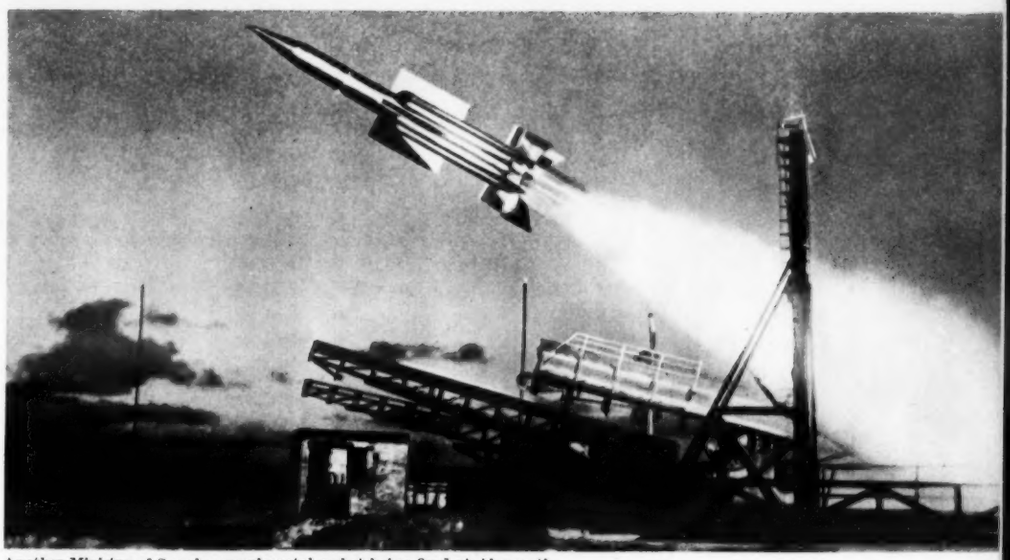
Among guidance and homing devices now under development in this country are advanced infra red heat homers (probably similar to that designed for the German *Wasserfall* anti-aircraft rocket in which a mirror reflected infra red rays through a rotating disc to a photo cell, in turn triggering a relay circuit to operate the controls); magnetic radiation detectors of very high sensitivity; electro-gravitic devices; and various types of audio detectors supplying bearing and range information to the control mechanisms. Good progress has also been made in building hyper-sensitive proximity fuses.

American aid was sought after 1949, and some firms (e. g., Bristols, who have an agreement with Boeing) were able to draw on the experience already gained in the States.

A complete missile project is treated as a weapons system with one firm specified for structures, another for power and a third for guidance. For instance, the Sperry Gyroscope Co. provides the guidance system for an Armstrong Whitworth ship-to-air missile powered by an Armstrong Siddeley motor. Only one company in the United Kingdom can fulfil all three requirements from within its own organisation, and this is English Electric. The parent company build the "airframes" and some research test equipment, Napiers build the power plants, and Marconi's the guidance.

Other major companies heading particular projects are Armstrong Whitworth (and now other Hawker Siddeley firms), Bristols, Vickers, Fairey, de Havilland (Propeller Division). Firms engaged on missile engines include de Havilland (Engine Division), Bristol, Fairey and Armstrong Siddeley.

The projects cover the whole field of surface-to-surface (tactical and strategic), surface and ship-to-air, air-to-air and air-to-surface missiles (including the much discussed free falling guided bomb). Now work has started on a British intercontinental ballistic missile (IBM) to have a hydrogen bomb warhead.



Another Ministry of Supply experimental rocket being fired at Aberporth.

Little is known about specific projects, but the following is a list of missiles revealed to date with data on them collected from published reports.

— Armstrong Whitworth are building a ship-to-air missile with four sets of "wrap-round" booster motors. Following extensive trials at Woomera, the type will go into production soon. The Admiralty reveals that it will test such a weapon on the guided weapon ship *Girdleness* next year.

— English Electric are nearing the production stage with a 2,000 m.p.h. anti-aircraft missile, ground-fired and capable of intercepting bombers above 50,000 ft. In this case the test vehicles (which have been fired at Aberporth and Woomera) have a main rocket motor plus four sets of twin overlapping boosters.

— Bristols have shown photographs of their ramjet test vehicle experiments. It may logically be assumed that, as Bristol have close liaison with Boeing on missiles, a design for a ramjet anti-aircraft weapon of the Boeing *Bomarc* class—Mach 2, altitude 60,000 ft.—may eventually emerge.

— De Havillands are working on air-to-air missiles suitable for mounting on such aircraft as the *Javelin*. De Havilland test vehicles exhibited bear a resemblance to weapons shown being fired from a *Meteor* night fighter. American sources state that these missiles have infra red "heat-homers". This may be the air-to-air missile reported by the Minister of Supply as having already been ordered into production.

— Faireys are believed to be working on various rocket types and also special delta winged weapons developed from the much publicised Fairey VTO.

— Vickers' activities have been little mentioned but in view of the tremendous amount of research the company has put into the aircraft-dropped bomb (e. g. the spinning bomb which burst the Möhne and Eder dams) it is logical to assume they have an interest in the guided free-falling bomb which the R.A.F. requires.

All the main firms together with a growing number of the power plant and guidance manufacturers have set up bases at Woomera in Australia. It has only been during the past year that Woomera has really begun to contribute its full benefit to the British firms, with the delivery of advanced computers and testing equipment. Meanwhile, special missile research programmes and many individual tests are still carried out at Aberporth on Cardigan Bay in Wales.

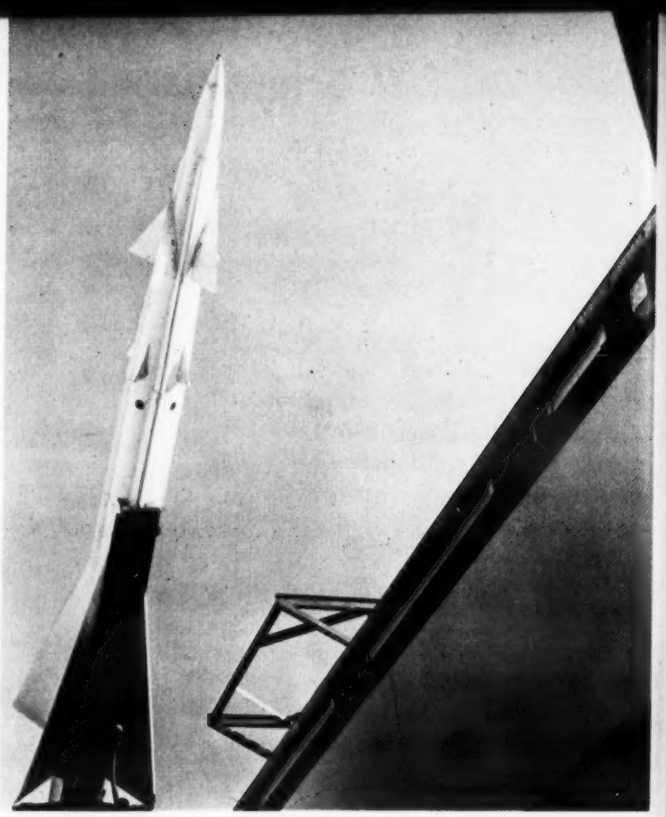
Rocket assembly at a Ministry of Supply Establishment.

"NIKE"

Nike, Greek mythology's winged Goddess of Victory, is one of three anti-aircraft missiles which will soon become operational with the U.S. forces: the U.S. Army has the local-defence *Nike,* which was developed by Western Electric (manufacturing unit of Bell Telephone) and is being produced by Douglas Aircraft; the Navy is operating the shorter-ranging Convair *Terrier* for defending its ships; and the Air Force is developing the Boeing *Bomarc* pilotless interceptor for longer-range defence.

At present the Army is ringing some of the major target areas in the U.S.A. with *Nike* bases. Washington is to receive about twelve, and at least one—at Lorton, Va.—is ready for operation. More than a dozen are to be provided around New York, including one on Harts Island in Long Island Sound, at Fort Tilden and at Fort Hancock, all three of which are nearly completed.

Construction of each base costs between $500,000 and $750,000, depending on terrain conditions. Judging from official photographs, each base comprises four missile launchers. The heart of a base consists of two underground concrete magazines measuring about sixty feet square and capable of storing about sixteen of the 20-foot, supersonic *Nikes.* Each magazine also houses two of the launchers which are placed in position above ground by elevators. Thus, an average base has about 32 of the missiles, or eight to each launcher. Since each *Nike* costs $25,000, the investment in missiles alone amounts to about $800,000 for each base.



A *Nike* on its launcher rises on an elevator through a slit in its concrete underground bunker.

In the concrete underground installation of the Lorton, Va., missile launching site U.S. Army personnel scramble to their positions during a practice alert.

The *Nike 1* missiles now being issued to air defence units are claimed to be capable of knocking down bombers flying at altitudes between 20,000 and 60,000 feet at a range of up to 25 miles with reasonable accuracy. They are guided to their targets by radar and electronic computers from special control bases which control a whole system of launching bases.

Already, however, Western Electric and Douglas are working on a much larger type, the *Nike B,* details of which are secret. However, at the end of January it was disclosed that U.S. scientists have completed an atomic anti-aircraft shell for the *Nike* which could destroy all aircraft flying within a path more than half a mile wide—an advantage in the case of bombing attacks by mass formations. The shell in question

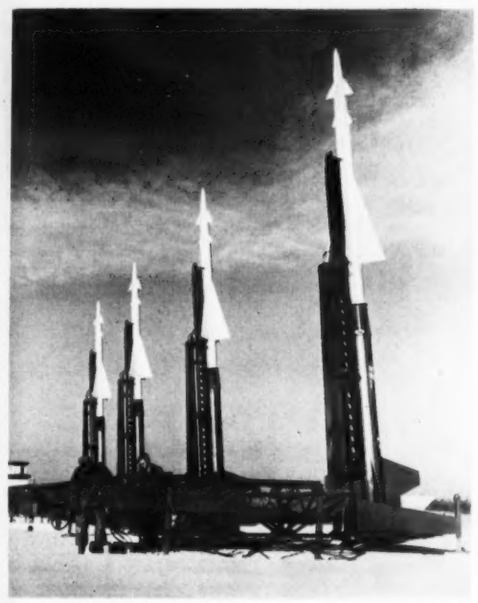
The *Nikes* are inspected prior to raising them to the launching position above ground.

The ways of "NIKE"

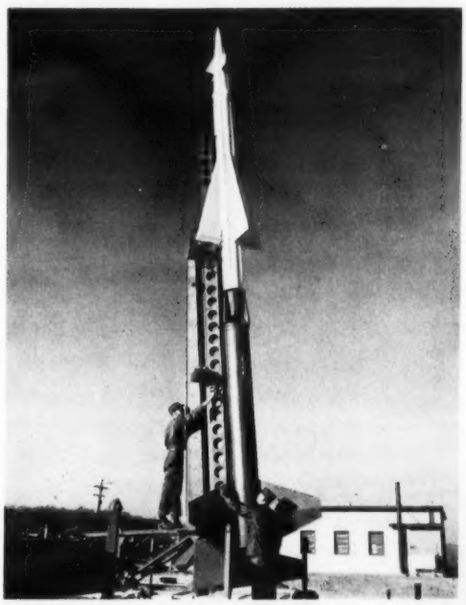
1. *Nike* anti-aircraft missile (lower left) nearing the starboard wing of a radio-controlled Boeing B-17 *Flying Fortress* drone bomber. The smoke pot under the wing serves for identification purposes.
2. The *Nike* is about to strike.
3. The *Nike* has hit and explodes upon impact.
4. The target is ripped apart.
5. With wing shattered and on fire, the B-17 drone starts its final plunge.
6. As the aircraft plummets to earth, an engine tears loose and proceeds upwards "under its own power"

A missile ready to be raised to its vertical firing position.

The whole battery is nearly ready.



Ready for firing. The lower, dark portion of the missile is the booster, which drops off at a certain altitude.



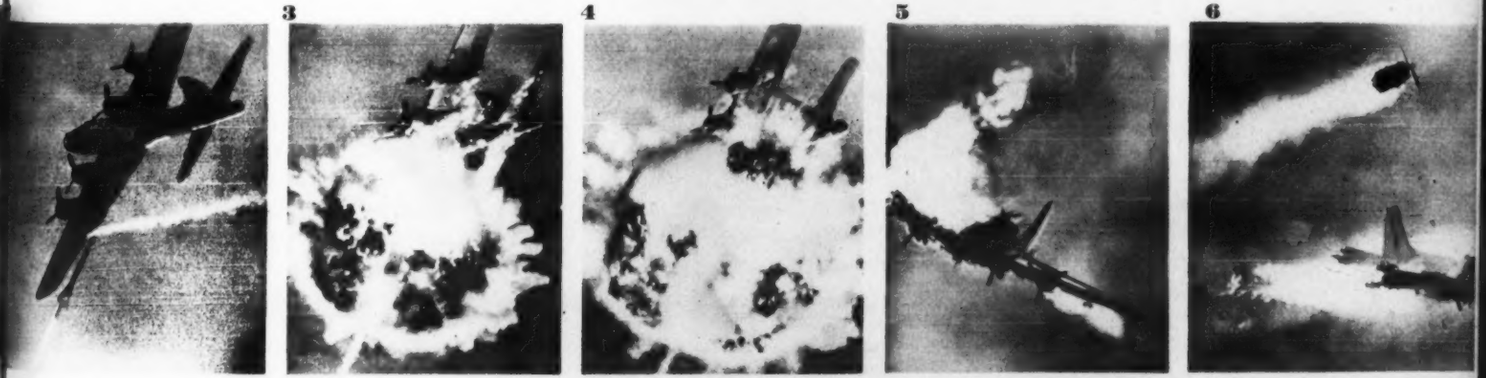
Last adjustments are being made.

Fire!... and whoosh, a *Nike* is on its way. This photo was taken at White Sands Proving Ground, New Mexico.

is believed to have been tested in Nevada in February. In quantity production each warhead is estimated to cost about $100,000.

The main question to be resolved is whether such atomic shells could be used in the vicinity of cities and their heavily populated approaches. At any rate they could be detonated only at great altitude—50,000 feet or more—without causing serious local damage.

If the *Nike* is as effective as it is said to be, bombers had better stay out of its way. The result may be that increased emphasis will be placed on the development of strategic air-to-ground missiles which could be launched from aircraft against a target several hundred miles away. Both Americans and Russians are believed to be working very hard on such missiles.



Guided Missiles for Home Defence

BY COLONEL (RETD.) H. ALDINGER, MUNICH

The author, now 48, began his career as a professional artillery officer with the German Reichswehr. During World War II he transferred to the Anti-Aircraft Artillery and was attached for a time to Luftwaffe High Command. After the war he attended the State School of Building in Munich (civil engineer and architect); in 1952 he worked for the Blank Office, from 1952 to the beginning of 1955 for the Radio Navigation Committee in Düsseldorf; on April 1st, 1955 he joined Telefunken, where he is concerned with electronics and air defence. Editors

During World War II the strategy of air warfare led to the creation of a second front inside the belligerents' home territories, a second front which became of decisive importance. Wherever defence of rear areas was neglected or broke down under the weight of enemy raids, the battle was lost on the fighting front.

Since 1945 the means of aerial attack have developed by leaps and bounds. Aircraft speeds are now in the sonic region, and further increases up to twice the speed of sound are to be expected within the next few years. The effectiveness of bombing raids has been multiplied many times by the A- and H-bombs. It is no wonder that fear of a future air war now dominates all nations. Thus air defence has become one of today's most burning problems.

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The means available today for warding off mortal danger from the air include not only fighters and conventional anti-aircraft guns but also guided weapons. While fighters have so far retained their old value and will probably continue to do so at any rate in the immediate future, the effectiveness of anti-aircraft guns against raiders flying at altitudes of more than 20,000 ft. has become very doubtful. Britain for one has therefore decided to do away with a good proportion of her heavy anti-aircraft artillery. For defence against high-flying raiders guided anti-aircraft missiles are replacing anti-aircraft guns to an increasing extent.

To judge from the specialist press, the sequence of measures to defend an area against enemy air raids would be roughly as follows:

Warning received through long-range radar over distances of several hundred miles; take-off and interception by fighters; firing of long-range rockets over distances of about 60 miles; local defence by smaller rockets. In other words, *advanced defence* along a coastline or frontier over the longest possible ranges, and *defence of specific targets* on the same lines as with the old anti-aircraft artillery but at greater distances from these targets.

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Would this method of defence really stand up to a modern air war, or is it advisable to prepare additional defence measures? The principle of advanced defence, which is perhaps the most natural, and that of target defence lead to the logical conclusion that an attacking aircraft must be intercepted before it arrives. This, however, obliges the defence, in view of the growing speeds of bombers, to demand increasingly long ranges, so as to extend the advanced defence field as far as possible and increase the time available for interception.

The result is that guided anti-aircraft missiles are growing bigger and bigger, and, as range increases, technical demands on the guidance system become more exacting. To make good the inaccuracies of guidance over long ranges, large warheads are needed, and the increase in the effect of an enlarged warhead is in a very unfavourable ratio to the transport performance required. Then there is the additional disadvantage that with present guidance systems projectiles have to be guided from the ground throughout their trajectory. Thus the greater the range required, the longer will be the guidance times necessary. This in turn has an adverse effect on rate of fire. The high aircraft speeds oblige the defender to tackle the attacker from the rear, and the anti-aircraft missile must be guided round in a curve to the rear of its target, thus wasting a relatively large percentage of its range. The inevitable impression is therefore that, as aircraft speeds increase still further, insistence on advanced defence must lead to exaggerated technical demands on guided missiles, which are already costly enough.

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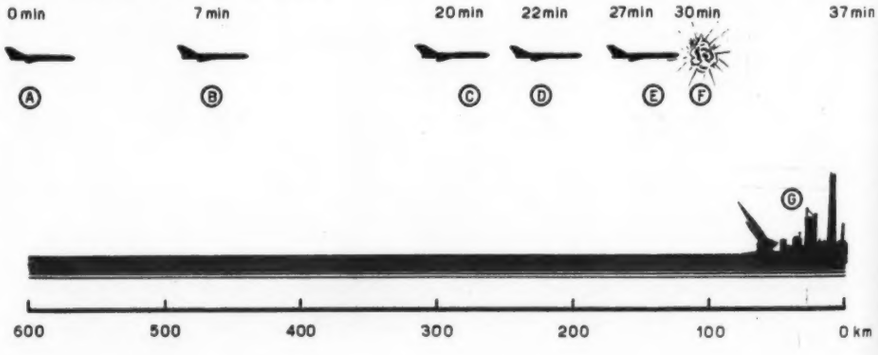
For some regions, such as the United States, it may be assumed with some justification that air raids can only be expected from small, very fast and very high-flying bomber formations carrying A-bombs. For the United States, therefore, it may be permissible to adapt the defence to such *small* high-flying units and hence to concentrate, in their development of guided anti-aircraft missiles, on increasing range.

What of conditions in Europe, however?

In the event of an attack from the East, most countries in Europe are within an hour's

Sequence of defence measures against air attacks for combined defence by piloted fighters and guided missiles: *A:* first radar detection of enemy (at a distance of several hundred miles); *B:* take-off of interceptor fighters; *C:* fighters engage the enemy; *D:* guided missile batteries warned; *E:* guided missile batteries open fire; *F:* guided missiles reach the enemy; *G:* the target to be defended (city).



flying range. All these areas in Western Europe could be raided by slower bombers, and there appears to be no reason why, in the event of war, attacks might not be made by large numbers of aircraft, on the World War II pattern. The Eastern bloc's large-scale production, reported in the press, would support this assumption. What is more, in view of the short distances involved, the bomber formations could be adequately protected by escort fighters. It is also doubtful whether in an attack on Western Europe A-bombs would be used near the frontier, since the attacker would presumably wish to occupy such territory as intact as possible, so as to be able to utilize its industrial potential. It would therefore appear to be very dangerous to regard raids by small formations as the only possible form of attack in the future and to build up home defences only on this basis. If, however, the possibility of large-scale raids is envisaged, the question arises of whether *the heavy anti-aircraft missiles now in development suffice, with their low rate of fire, for a really successful defence.* The principle of advanced defence may be all very well for the protection of frontier or coastal targets. But for the protection of the rear areas as a whole, the system does not seem adequate, particularly in Europe, whose dense population and high degree of industrialization make it into one vast target.

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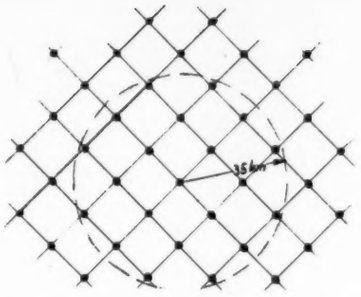
If this argument is correct, it would seem expedient to abandon the system of protecting isolated targets for that of *area protection.* Such an area could best be protected by guided missile batteries set up on a sort of checkerboard system, resembling a "*mine field*" into which any attacker would be obliged to fly. By careful choice of the distance between the batteries, both the number of batteries could be kept relatively small and the range requirement limited.

The system would have the following advantages:

1. A *raider could be continuously attacked* from the beginning by at least four batteries or, at greater altitudes, by six to eight batteries. There would be no lightly defended areas by which the enemy could approach. Not only isolated targets, but the whole area would be protected. Danger of surprise attacks is reduced to a minimum. The amount of ammunition fired against the enemy is greater, since considerably more batteries get a chance to fire than if they were grouped round isolated targets. Aircraft with rocket bombs can be attacked in good time, at any rate inside a country.



A checkerboard arrangement of anti-aircraft guided missile batteries would have a number of advantages: several batteries could engage the enemy simultaneously, the batteries would not be obliged to attack an "approaching" enemy, batteries need not be moved, and ground defences, being less concentrated, would be more difficult to saturate.

2. *The batteries are not obliged to fire at an "oncoming enemy".* This fact is of particular importance, as it considerably reduces technical requirements. For firing at an oncoming aircraft, the speeds of the raider and of the guided missile used against it are cumulative. Hence very high demands must be made on the guidance system or the target-seeking head, or the missile must be guided round the raider in a curve so as to approach it from the rear. If the latter method is used, it is at the expense of range and rate of fire, a distinct disadvantage in view of the short periods of time available for defence against an oncoming target.

For firing at a "departing" target, on the other hand, the speeds are subtracted. Also, the missile need not follow a curved path, so that it can be made smaller, and the guidance system can be simpler.

3. During World War II the ground defences were obliged constantly to change their operating areas, because of the constant change in bombing targets. *Such movements would not be necessary in the network system of area defence advocated here.* It is therefore possible to build up the defences on a kind of militia standby organization. This would avoid aimless "standing around" by anti-aircraft units (when no direct attack is in progress) and its effect on morale. A real "self defence" force could be built up, on the lines of a home guard. If the anti-aircraft missile batteries are sited close to factories, technical workshops and the like, suitable personnel can be chosen in peacetime from the staff, from age groups no longer liable for call-up for active duty with the armed services. This personnel can then be exempt from call-up in wartime. The result would be a greatly improved nucleus of personnel for the batteries. Moreover such personnel would be defending their own home districts, which would be impossible in an ordinary military organization. At the same time the question of unit leaders would be simplified, since engineers from the industrial premises to be protected could take over these duties.

For batteries in the immediate neighbourhood of the frontier or set up in concentrations within the basic network, the above standby personnel should be replaced by permanent teams of older reserve age groups.

Those who remember the constant change in personnel structure in Germany's ground defences during World War II and the consequent reduction in efficiency, will recognize the interest of the above suggestions.

4. *It is much more difficult to saturate the ground defences in such an area defence system.* In addition, cooperation with the aircraft observer service, also organized on the same network system, is much easier.

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In any form of defence, including the area system, the important point is ultimately always that as much fire power should be brought against the enemy as possible. Consequently anti-aircraft missiles must be developed which are much smaller and easier to handle than those at present known. Admittedly the new defence system described above, though alleviating the technical problems, would not provide any guarantee of a fully effective defence. The rocket power plants in use today are too cumbersome. It may be assumed, however, that use of more modern power plants, such as ramjets, would enable missiles to be made much smaller. It would also be advisable to introduce a guidance system capable of guiding as many missiles as possible to a bomber unit simultaneously.

The aim of technical development must be to evolve a small, cheap missile, so that even large formations of enemy aircraft can be intercepted.

Obviously every effort will always be made to intercept the enemy, by means of individual long-range high-performance batteries, before he reaches the defenders' territory. The object of this article is merely to point out the advantages of area defence: exaggerated technical demands are avoided, a greater number of batteries can be fired simultaneously, and the system accords better with the personnel situation in rear areas.

In ground fighting no attack on the front can be warded off by highly-developed long-barrelled guns, nor can mass raids from the air be combated by oversize guided missiles. Just as, on the land front, the artillery battle is waged primarily with light field guns, so the protection of advanced areas against high-flying enemy raiders necessitates small guided missiles, whose high rate of fire makes them really effective against mass attacks.

The Rocket-Driven Commercial Airliner

BY DR. WALTER R. DORNBERGER, BUFFALO

Dr. Walter R. Dornberger, who will be sixty next September, was appointed Guided Missile Specialist for Bell Aircraft Corporation, Buffalo, N.Y., in May 1950 after serving in a similar capacity at the Wright Patterson Air Force Base of U.S.A.F. Air Materiel Command, Dayton, Ohio, for three years.

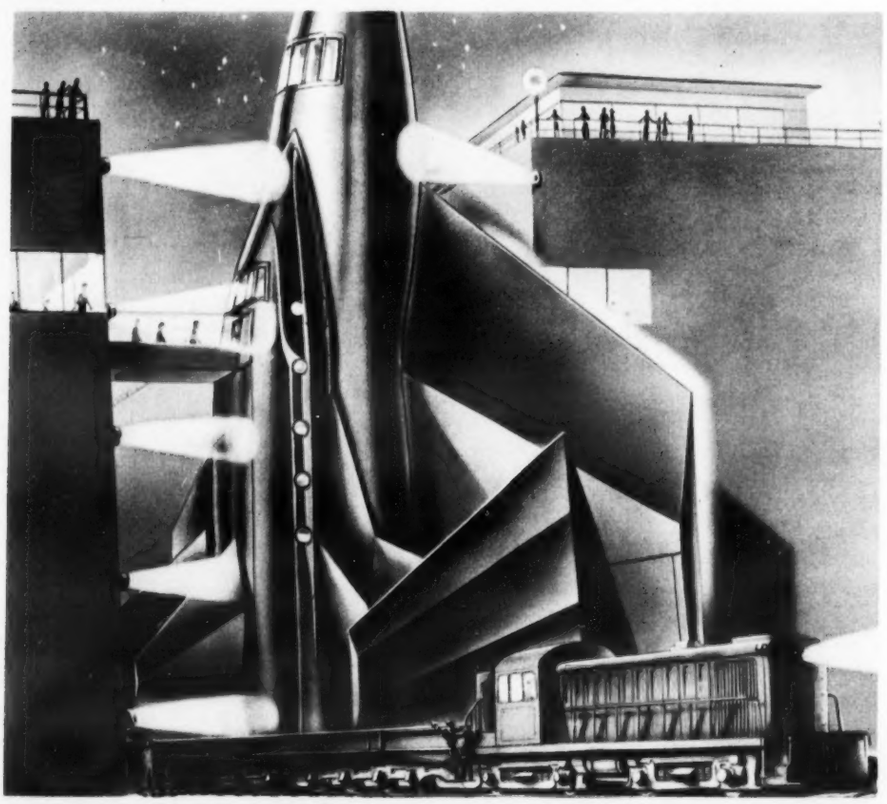
Dornberger took an early interest in rocketry and guided missiles. Born at Giessen, Germany, he volunteered for a German heavy artillery regiment upon the outbreak of World War I and was captured by the Allies in 1918. After the war he stayed on in the 100,000-man professional **Reichswehr** and studied Engineering at the Berlin Technical Institute. In 1930 he was given charge of the development of solid fuel rockets for use as modern weapons; a year later he shifted to the development of liquid-fuel rockets when he assumed command of the Reichswehr's new Kummersdorf experimental station.

During World War II Dornberger became Commanding Officer of the German missile research centre at Peenemünde, where the V.1, V.2 and Wasserfall weapons were developed. In 1945 he was captured by the Allies the second time, holding the rank of Major-General, and shortly after left for the United States.

Shortly before and during the last war, four new propulsion systems for flying vehicles were invented—the gas turbine engine, the pulse-jet, the ram-jet and the liquid-fuel rocket. But only one of these engines, the gas turbine, is presently being introduced in commercial air traffic.

Of the four power plants, rockets will give the highest speed to a vehicle, and I believe that in the not too distant future—in about forty years' time—rocket-driven airliners will be zooming through the sky. It is for economic reasons that the rocket power plant has so far not been regarded as a suitable drive for commercial aircraft. Therefore, if we assume that high flying speed is worth striving for, we must prove that (a) economy is obtainable by the proper selection of flight paths and (b) that a rocket-driven commercial aircraft is technically feasible.

The passenger-carrying rocket plane, riding piggy-back on its larger booster, is ready for take-off. Passengers board it by crossing a gangway in the "crater" wall, and are taken to their tilting seats by a small elevator.



To take the technical aspect first, we shall have to apply the experience which we are gaining with guided missiles to the design of rocket-powered airliners. These will have to have missile characteristics and will be flown on a flight path similar to that of long-range guided missiles.

Passenger-carrying rocket aircraft will be very large; there will be only comparatively few of them, and they will be used for the longest routes on the planet—like today's giant ocean liners. They will essentially serve inter-continental connections and may run on a few transcontinental routes.

In contrast with conventional propeller and jet planes, the rocket plane will not be driven continuously, but will be accelerated only for a few minutes. During this time, it will attain a speed which hurls it in free flight over distances of thousands of miles. From the great altitude reached at the end of the propulsion period, the plane begins its long glide path, which may last one hour or more, depending on its initial velocity and altitude. In spite of its shortness, the propulsion period will not be uncomfortable for the passengers, since large rocket-driven vehicles actually must take off at a very low acceleration, in order to avoid use of an excessive number of motors and too-heavy propulsion systems and in order to avoid high air-friction heat because of excessive speed within the denser layers of the atmosphere. It can be assumed that at the moment of take-off acceleration will amount to approximately 1¼ g, while at termination of burning, the point of fuel cut-off, acceleration will have reached 3½ g.

Aside from the shortness of its propulsion period, the rocket plane will differ in two other important respects from the conventional airplane. The latter relies on air for propulsion

The rocket combination and its splash plate is now taken to the centre of the crater. It is turned so that the edges of its wings are turned into the wind in order to avoid side movements in the initial stage of ascent, when the rocket climbs very slowly.

as well as for lift which it needs to keep on flying. The rocket plane carries an oxidizer in addition to the fuel and therefore is completely independent of air for its propulsion. This is necessary in order to attain the high speeds and altitudes required for its long glide paths. For many practical reasons, among them low cost—very important for commercial enterprises—it appears likely that the commercial rocket aircraft of the future will operate on the basis of liquid oxygen and gasoline.

In contrast with the conventional plane, the reliance of the rocket plane on air for flying depends on its flight speed. At moderate speeds —and even 3,000 miles per hour is still moderate in this connection—air is needed to support the plane's weight during the glide. But, as the speed increases, a new and significant effect makes itself felt. This is the centrifugal effect caused by the fact that the vehicle must follow a curved path due to the earth's gravitation. The higher the speed attained by the rocket plane, the larger is the portion of its weight which is supported by the centrifugal effect, and ultimately the ship is kept on its path exclusively by the centrifugal effect. Moreover, at its ultimate speed of about 17,400 m.p.h., air would but impede the rocket plane's motion. In order to attain and keep this velocity, the rocket plane must go above any atmospheric layer of appreciable density into empty space.

But, before the first large passenger-carrying rocket plane takes off, science and technology must close many gaps still existing in our knowledge and know-how of the art of flying at hypersonic speeds and at extreme altitudes. What we must learn may be summarized in four points:

1. We must learn to develop and operate large rocket power plants consisting not of one single huge motor, but of clusters of many motors. The size and thrust of the individual motors needed for rocket gliders flying halfway around the globe will not exceed the thrust performance of rocket motors already planned during the last war.

2. We must learn to design and develop airplane configurations that operate with reasonable efficiency at hypersonic, supersonic, as well as subsonic speeds.

3. We must learn to tackle the problems connected with the simultaneous mechanical load due to air pressure and the thermal load due to the high temperature of the compressed air in the immediate vicinity of the plane, particularly its nose and the leading edge of its wings.

The critical moment seems to be when the aircraft reaches a speed of around 10,000 m.p.h. At higher speeds the rocket plane can glide at such high altitudes (200,000 to 300,000 feet or more) as to reduce aerodynamic heating because of lack of sufficiently dense air. At lower speeds the plane must seek denser layers of air to find the necessary lift, but then the speed is no longer high enough to obtain the same high values of aerodynamic heating as in the critical region. At 10,000 m.p.h., which is only an approximate value for the critical region, the rocket plane is somewhere between 140,000 and 170,000 feet up, depending on its aerodynamic qualities. The skin temperature on its conical nose is then some 1,800 degrees Fahrenheit. On the cylindrical portion of its body the temperature is considerably lower, around 1,000 to 1,300 degrees Fahrenheit. This sounds intolerable for human flight, but actually it is only necessary that the skin of the plane stands these temperatures. This can be done with high-heat-resistant materials such as nickel alloys. The supporting elements, such as main beams and struts, will be well insulated underneath the skin so that they absorb less heat than the skin itself, which alone is exposed to air friction. The passengers' and pilots' pressurized cabins are, in addition, cooled by liquids pumped through a space between skin and cabin walls.

4. Last, but not least, we must learn to combine the principles that govern the flight of a guided missile with those applied in a piloted airplane. As to its mode of flight, the rocket glider stands between the airplane and the guided missile. An intercontinental rocket glider at cut-off behaves more like a projectile than an airplane. This condition prevails from

At an altitude of 70,000 feet the moment of separation arrives. The passenger rocket glides along rails on the back of the booster, then zooms upward under its own power, heading for its destination. The booster rocket glides back to the base of departure to be readied for another flight.

The rocket aircraft continues to climb, using its three rocket motors – for a total time of 136 seconds from the moment of separation. At 140,000 feet the motors are cut off, and at a speed of 7,300 knots the rocket begins its far-flung glide.

take-off, through power cut-off, into the glide phase, until the flight speed is reduced to about 2,700 m.p.h. During this time the pilot can only supervise, monitor, and adjust the automatic navigation, stabilization, and control equipment, which is very much like that of a guided missile. When the rocket plane's speed drops below 4 times the velocity of sound, airplane conditions are approached again, and soon thereafter the pilot can take over in a more or less conventional manner.

In order to impart the necessary speed to a rocket airliner, it will have to be attached to a booster. The passenger-carrying rocket plane will not be mounted in tandem ahead of the booster, but ride on it, piggy-back fashion. This limits the height of the combined set and makes it possible to give both vehicles an aerodynamical shape, enabling them to fly as individual airplanes. During take-off, the motors in both rocket planes burn jointly, but the motors of the second stage are fed with propellants from the booster plane. The booster in turn saves weight by using the motors of the second stage. The booster plane has its own crew, which, after separation, pilots the ship back to the airport from which the combination took off.

Imagine such rocket planes operating commercially at the turn of our century. A thin, but far-reaching, net of flight routes will lead across the globe. Assuming no major shifting of cultural and civilizational centers by that time, the rocket sky lanes will radiate from two major centers—U.S.A. and Europe—to all continents. In the U.S.A., the East and the West Coast will have one rocket airport each, say, New York and San Francisco. From San Francisco one line will lead nonstop to Tokyo with connections to Calcutta; another line will lead to Sidney via Hawaii. In Sidney and Calcutta transfer to other rocket liners will be possible, leading from Calcutta to London in nonstop flight.

In an eastward direction, the San Francisco rocket port will offer a flash connection to New York, from where you can fly nonstop to Rio de Janeiro, or to London, Europe's huge rocket port. Air taxi service connects each rocket port with all airports on the continent.

Thus, we will have the huge Pacific triangle, San Francisco-Hawaii-Sidney-Calcutta-Tokyo and back to San Francisco, and the smaller Atlantic triangle connecting New York, Rio and London. The London-Calcutta route will connect Europe with Asia; and the London Cape Town route will serve the traffic to Africa.

It will not be necessary to have a different rocket plane size for each route. Two types corresponding to the two main groups of distances will be sufficient. One type will have a take-off weight of 600,000 pounds, the larger class 770,000 pounds. Variation of the necessary flight speed within each group of routes will be accomplished by reducing or increasing the amount of payload carried.

The reduction in flight time accomplished by these rocket planes is spectacular. New York will be but a mere 1½ hours away from San Francisco, and even the long flight from Hawaii to Sidney, Australia, will take only a little more than 1½ hours. This must be paid for, however, with a lot of propellant. The small rocket plane consumes about 57,000 gallons of liquid oxygen and gasoline during each ascent; those of the larger class do the job with 75,000 gallons, their flight range being about 5,200 miles at the most, with 1,000 pounds payload from London to Cape Town. Under these conditions a ticket New York-San Francisco in the small rocket plane carrying about 20 passengers on this route, would cost about twice as much as it costs now.

The rocket plane will take off out of a so-called "Crater", a circular concrete-covered launching site into which lead 60-foot deep trenches called canyons. These canyons run straight from the maintenance hangars to the Crater which is on the same level as the canyons. A tractor pulls the 90-ft. high rocket plane on a special splash plate to the Crater, where it is turned so that the edges of its wings are directed into the wind in order to avoid side movements which might damage the ship on the crater-walls when pulling out into the open on stormy days. The ship is now filled with propellants from large tanks buried close to the rim. Not until the filling is completed and the vehicle is ready for take-off do the passengers arrive by bus from the main building a few miles away. An elevator carries them 20 feet underground near the rim. Through a short tunnel section, they arrive at a platform projecting from the vertical crater-wall like a balcony. The passenger space is in the 60-foot-tall rocket plane's midsection, close to its center of gravity to secure smooth riding. In front of the passenger space is the fuel tank whose pipelines run through a special conduit to the tail section which contains the liquid oxygen tank and the motors. The pilot's compartment is in the nose.

The rocket plane takes off vertically. But soon after leaving the ground it begins to tilt toward a horizontal flight position, a process which is not completed until the passenger "stage" has attained its maximum speed.

We board the rocket plane through the entrance hatch at the upper end of the passenger section. A light elevator runs down to seats in tiltable plastic bowls on the left and right, one below the other at the presently vertical position of the rocket plane. The plastic bowls will rotate about their horizontal axis during the flight, so that the passengers will always sit in the most comfortable position. The hostess helps us to get into our seats and

to fasten our seat-belts, but she will not accompany the ship on long routes: limitation of payload forbids that; and no hot meals will be served because of the short flight time.

And here is how we shall travel from San Francisco to Sidney. The hostess welcomes us:

"In exactly five minutes we will take off. The motors of the booster plane as well as of our plane will operate together. The booster has five motors; our plane operates with three motors. Together, they deliver a thrust of some 760,000 pounds. You will not be bothered by excessive noise from the motor section, since the oxygen tank in between will absorb most of the sound and vibration.

"At the beginning of our free glide we will be 145,000 feet or 29 miles high. You will notice that a dark glass covers the inside of your normal window. It serves to protect your eyes from the radiation of the sun—at this altitude. You cannot shift this inner glass aside until its holding mechanism is electrically unlocked by the pilot. This will be done at a lower altitude where your eyes are no longer endangered . . .

"The company is proud of its safety record and takes every conceivable precaution to further increase your safety during the flight. Our rockets have outstanding reliability. However, should trouble occur in the motor section during the burning phase, the pilot would jettison the tail section containing the oxygen tank and the motor section and dump the gasoline out of the fuel tank. With the front portion of our plane, we would glide to safety without your having to leave your seats.

"The burning of the motors last only 4½ minutes. The remaining hour and 10 minutes that you ride will be very comfortable and quiet. I hope you will enjoy your trip very much. Thank you!"

Our entrance hatch is closed. Outside they retract the telescope-type gangway leading to the rocket plane, retreat from the platform into the tunnel, and close heavy steel doors. The usual "No Smoking" and "Fasten Your Seat-Belts" signs appear, then a red sign flashes up: 3-2-1-go! Beneath us eight huge rocket motors ignite. The fire which furiously erupts from their nozzles illuminates our wings and the walls of the Crater. It is early in the morning, the sky already has the blue transparency which heralds the imminent sunrise.

Then, we are captured by a strange new sensation. A fantastic power tightens its grip on our vehicle, and pushes this 600,000 pound tower upward, slowly but irresistibly. We rise above the Crater into the cool morning sky. The earth falls away beneath our blazing jets. As we gain speed and altitude, our rocket plane begins to tilt into horizontal position; but still we are climbing. Our seats tilt in the opposite direction so that we always have the most comfortable position, with our bodies pressed into the seats. The rocket plane's acceleration is too small to be disturbing. At the moment of take-off, a clock began to count the seconds. Continuously the big hand moves toward the 130 second mark; and there we are, still climbing at an angle of 10 degrees with respect to the horizontal, 70,000 feet up and 30 miles west of our launching site. The moment of separation has arrived, the most exciting event of the whole flight, for both passengers and pilots. The pilots in the final and in the booster stage exchange remarks via intercom. Our pilot actually is in control of both planes until the booster pilot takes over his plane after separation. He tilts both ships nose-down into a slightly negative angle-of-attack, in order to facilitate separation. The motors of the booster plane have ceased to burn. Then he lets go the holds which kept our plane rigidly connected with the booster plane. Rapidly our rocket plane glides along rails over the back of the booster plane. As soon as we are separated, our plane again turns its nose skyward, while the booster plane remains in its position. Drag and thrust quickly drive us apart. Then we lose sight of the booster plane which falls back or rather seems to fall back into the bottomless depth beneath us. We climb, 80,000, 100,000, 120,000 feet, but, above all, we now pick up speed along our more than 150-mile-long runway in the sky. Finally, 136 seconds after separation, we are 140,000 feet high. The motors are cut off. At the fantastic speed of 7,300 nautical miles per hour we begin our far-flung glide path.

The sudden silence is strange. The earth is far beneath us, strangely remote; but space is near. The early morning hour was selected for departure for our western flight to keep the sun behind us as much as possible, in order to avoid excessive glare and still give the pilot, in the nose section, good visibility with respect to the earth. The outside air pressure is but one five-hundredth of what it is on the ground.

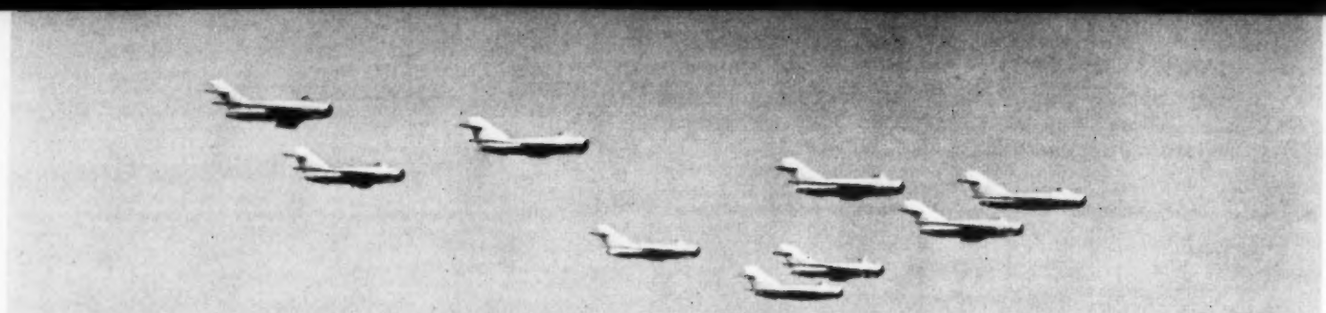
Time passes quickly. The sky begins to brighten, the stars begin to fade. Gradually we are losing altitude. The Hawaiian Islands appear on the forward horizon, green and yellow spots in the bluish ocean. A few minutes later we touch the ground on the Honolulu rocket port.

There, we are informed that we have one-half-hour time for a light breakfast before we can board the bigger rocket plane which will carry us over the 4,000 miles to Sidney in a little more than 1½ hours. Being bigger than our rocket plane which brought us to Hawaii, our new vehicle flies even higher and faster, but for the passenger the trip will be no different.

At 6.00 o'clock in the morning, Pacific Standard Time, we started from San Francisco. At 9.30 o'clock, Pacific Standard Time, we arrived at Sidney. If we did not have to add one full day when crossing the International Date Line from East to West, it would have been a real fast trip.

From Sidney, London is only 3½ hours' flight time away, not counting the layover time in Calcutta. This generation, for the first time in the history of mankind, obtains a practical conception of the earth as a small unit in space.

The rocket airplane at its destination, having covered 2,200 nautical miles in 1 ½ hours and landed at a gentle 100 knots. The larger type rocket will fly about 4,000 nautical miles in approximately the same time.



How Impenetrable is the Iron Curtain?

Outline of the organization and production of the Russian aircraft industry

To quote Shakespeare: As you like it! Every week **Interavia's** Editors get at least one letter from a reader asking the same question in one form or another: you write regularly about industry and production in almost all countries. Why do you never say a word about Russian aviation?

The Editors might reply that the reproach is unmerited, as the subject has been dealt with fairly extensively more than once in recent years[1]. The November 1949 article created something of a sensation, as the "guesstimate" of 20,000 Russian combat aircraft was taken up by all official and semi-official commentators. The Editors got a bit worried about what they had started. So they cautiously headed the October 1950 article: "There is no such thing as an 'old Russian hand'; there are merely those with varying degrees of unenlightenment." And when, following the general trend of development, they returned to the subject again in August 1954, they quoted Sir Winston Churchill on Russia: "An enigma wrapped in mystery."

Now some readers would like **Interavia** to join the ranks of the unenlightened or—to put it more drastically—to help solve the enigma . . . A thankless task!

The Editors have, of course, noted that some of their colleagues, with praiseworthy courage and optimism, have taken the responsibility of publishing drawings or even photographs. Meanwhile, the Russians have in no way changed their attitude, and continue to keep their own counsel. **Interavia** cannot make them talk, nor is it part of the Editors' duties to travel round Soviet territory with a camera in their button-hole.

It must therefore be admitted honestly that the subject is not one which, in present circumstances, the Editors enjoy tackling. Their **Review** articles are normally based on first-hand information received either through their offices and correspondents, or direct from official agencies or manufacturers. As they have no direct contact with such sources in the Eastern bloc, the following venture into the tricky subject of organization and production of the Russian aircraft industry must be taken for what it is—a collection of second-hand information. In this case, however, the information does appear to be fairly reliable.

But no guarantee of accuracy can be given. There is no such thing as an "old Russian hand", there are merely those with varying degrees of unenlightenment.

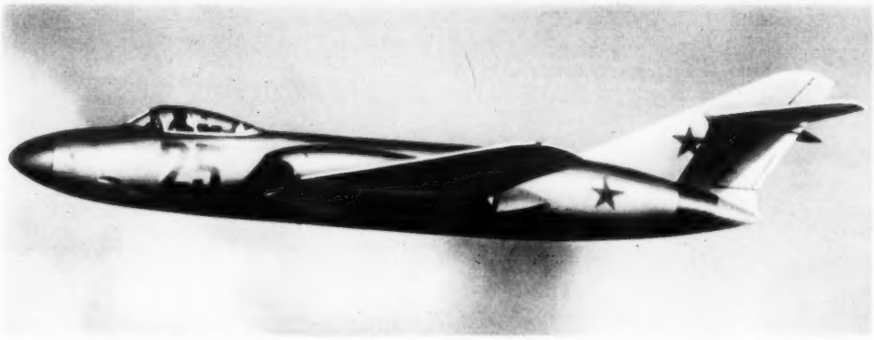
The Editors.

[1] *Interavia*, No 11, 1949: "Red Stars in the Sky", pp. 641—649; No 10, 1950: "Presentation of Arms in the East", pp. 511 - 516; No 8, 1954: "Aviatsiia Dalnego Deistviia", pp. 520-521, etc.

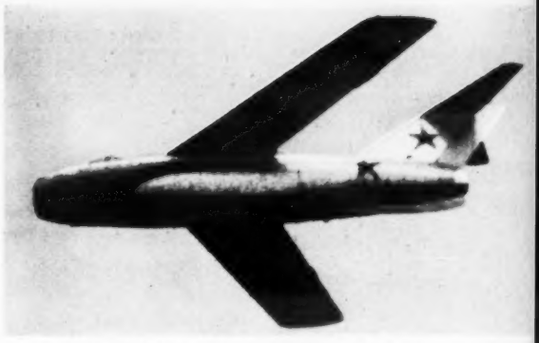
The Red Air Force's annual May Day Parades provide clear evidence of the metamorphosis that has taken place in the Russian aircraft industry since the end of World War II. Each of these gala presentations of new aircraft is eagerly awaited by Western observers. It is, of course, doubtful whether such carefully planned demonstrations provide exhaustive information on organization and trends in Russian aircraft production. Any assessment of the Soviet air forces' equipment is necessarily restricted to speculation on new types seen from a distance. Moreover, in order to ensure the maximum confusion, the Russians sometimes parade the strangest decoys, which rarely actually fly. Wooden mock-ups are placed on the airfields in the Russian Zone of Germany especially to mislead the Western

A Russian MiG-15 interceptor taking off.

The MiG-15 F two-seat night fighter version features a "radar nose" above the air intake.



A twin-jet all-weather fighter designed by A. I. Mikoyan has frequently been referred to in the Western press as the "Super MiG."



The La-17 escort fighter and ground attack aircraft is probably in service in fairly small numbers.

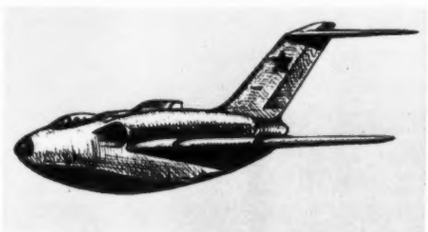
powers' intelligence services. Finally, to complete the mystification, "reliable" photographs appear, showing these decoys "in flight".

Russian aircraft development of the past decade falls into three distinct phases: 1) the immediate post-war period, during which the only aircraft available were developments of proven front-line aircraft, e. g. *La-11, Yak-11, Tu-2* and *Tu-4*; 2) the so-called interim period, characterized by jet-powered transition models such as the *Yak-15, MiG-9* and *Tu-8,* designed to be rapidly available pending the creation of modern combat aircraft with more powerful jet engines; 3) the present modernization phase, in which a long-term procurement programme is to bring the Red Air Force up to the standards of the Western air forces. The first aircraft types of this period are the *MiG-15* and *La-17* fighters and the *Tu-12* and *Il-28* tactical bombers.

Reorganization of industry and research

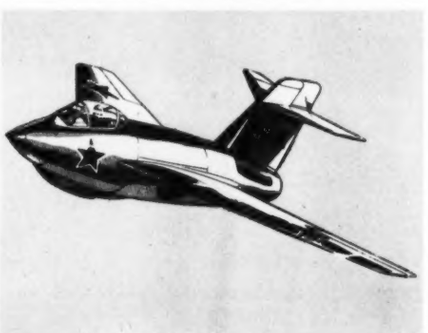
Scarcely had special Russian units begun the systematic evaluation of German research reports, projects and production processes than the U.S.S.R.'s planning commission received alarming reports showing how backward the Russian aircraft industry was. No less impressed by the progress in American and British aeronautical engineering at the end of the war, the planning commission—headed at that time by Voznessenski—urged the immediate preparation of a long-term modernization programme for the Russian Air Force. The documents captured in Germany were to provide the bases for further research. To speed up modernization, the Russians ignored their usual security methods and set up "research departments" and "technical bureaus" in their zone of Germany, where German experts were to help prepare the most important projects for production as rapidly as possible.

By the time the majority of these centres, including their staff, were moved into Russia in the winter of 1946-47, the Western powers' intelligence services in Germany had already gathered a more or less clear picture of the line of development being followed by Russian research. In some cases these assumptions were later strengthened by returning German scientists and released prisoners of war. When the Korean war broke out there remained little doubt that the Russian aircraft industry had come close to the technical level of the Western countries. Final confirmation came with the 1949 and 1950 May Day Parades and the mass employment of the MiG-15 in Korea.

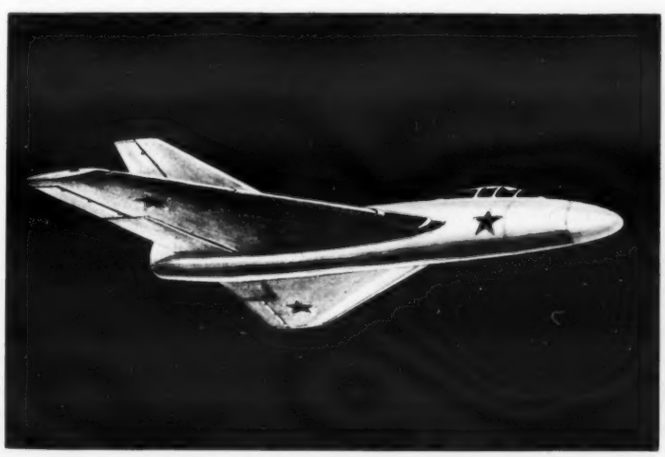


A twin-jet fighter flying boat designed by Colonel General A. S. Yakovlev was tested near the White Sea base of Magadan I in 1953 and 1954.

The Yak-21 rocket-powered local defence fighter has a rate of climb of more than 16,000 ft./min.

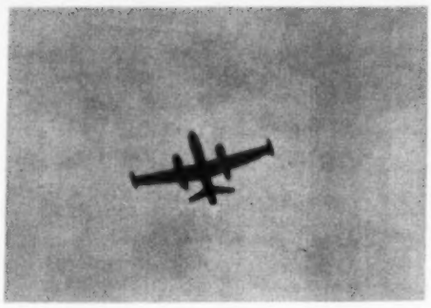


A night fighter developed by Cheranovski has a delta wing and sharply swept rudder unit.



This twin-jet all-weather fighter by an unnamed designer has an unusual aerodynamic configuration.

A development of the Il-28 with swept-wing has been stationed in the Russian Zone of Germany for several years.



The Il-28 twin-jet bomber is still standard equipment for the Tactical Air Fleet.

Developed by Junkers engineers in Germany, the EF-150 twin-jet bomber is unlikely to go into production.

Less attention was given to the fact that the Russian Ministry for the Armed Forces had set up a laboratory for jet research just outside Moscow as early as 1942. Its task was to investigate the jet propulsion theories elaborated by Prof. Stekhkin. The Central Institute for Power Plant Research (Z.I.A.M.) in Moscow, headed by Chief Engineer Kostikoff, made interesting experiments with gas turbines working on the Whittle principle. In 1943 Prof. Stekhkin and Z.I.A.M. developed the first practical turbojet, which began test runs towards the end of the same year. Quantity production was planned, but production difficulties prevented its introduction during the war. A fighter designed by Yakovlev and fitted with this engine is said, however, to have flown in the autumn of 1944. This may have been a predecessor to the Yak-15.

Shortly after the war Russian specialists succeeded in continuing development of captured Junkers and B.M.W. jet engines. Without knowledge of high-speed aerodynamics and thermodynamics, Russian engineers would scarcely have been able, even with German assistance, to build a 13-stage axial-compressor engine with a thrust of 6,600 lbs. as early as 1947. That the Russians today have jet engines with thrusts of 11,000 to 13,000 lbs.—if not more—would seem to prove that their basic notions of jet propulsion do not merely date from 1946.

On the other hand, the Russian aircraft industry had ample time for thorough testing of new jet engines. During the transition period to the long-term modernization programme more than a thousand Jumo 004 and BMW 003 gas turbines, either captured complete or assembled after the war, became available. These sufficed to power the hastily designed MiG-9s and Yak-15s.

However, none of the types designed during the interim period (roughly 1946 to the end of 1948) were developed for large-scale production. It would not have been possible to reduce the production of older standard types in favour of a large number of jet-powered interim types without seriously endangering the industry's overall output for at least eighteen months. The small number of Rolls-Royce *Derwent* and *Nene* jets obtained from Britain also did not permit of long-range planning. Production of the *Nene* copy was not yet under way, and it would hardly have been worth developing maintenance and works installations for the odd fifty Rolls-Royce engines. It is obvious today that the British gas turbines were acquired merely for a few prototype aircraft and for test purposes in the development of the improved Russian copy of the *Nene*.

The Russian gas turbine designer B. Chelomei also designed an axial compressor engine with a static thrust of about 6,600 lbs., which was to have gone into production during the winter of 1947-48. This plan had to be dropped at the time, as the engine was not ready for production. Design difficulties with cooling the combustion chamber walls and with the movable tail pipe cone are said to have been responsible for the delay. Russian designers had already encountered the same difficulties in developing the BMW 018 twelve-stage axial-compressor engine.

Three-view drawing of the Il-28 showing the manned rear gun position and the radome under the cockpit.

On the other hand, production of the RD-45 radial-compressor engine began as soon as modern plant had been constructed at Gorki and Kuibishev.

The modernization programme was accompanied by personnel changes in the procurement office of the Air Department, Ministry of the Armed Forces, soon followed by a reorganization of the tactical air units. Voznessenski, Marshal Vershinin (at that time Commander-in-Chief of the Red Air Force) and Lieutenant General Chrunichev (now a Second Vice-Premier) instituted reforms in the Russian aircraft industry at the end of 1947. A major preoccupation here was apparently to arrive at a closer coordination of the widely decentralized airframe and engine plants. The creation of new plants for jet engine production—at first the automobile industry was included in the programme—was probably the decisive step towards fulfilment of the modernization programme.

The first tangible results became apparent to the Western World with the advent of the MiG-15 jet fighter and the Tu-12 and Il-28 tactical jet bombers. All powered by the RD-45 (*Nene*) engine, these aircraft were stationed in squadron and wing strength in a number of frontier areas of the Soviet realm. Soon there were signs that a long-range strategic bomber fleet was being built up. The above-mentioned aircraft had filled a gap in Russian air arms, so that several plants could now concentrate on medium and heavy jet bombers. Two years ago the prototype of a 75-ton long-range bomber, designed to replace the obsolescent Tu-4 (copy of Boeing B-29) and to be fitted with either four diesel engines (development of the Jumo 224, approx. 4,450 h. p.) or four propeller turbines, made its appearance. Whether this type, the TuG-75, is already in

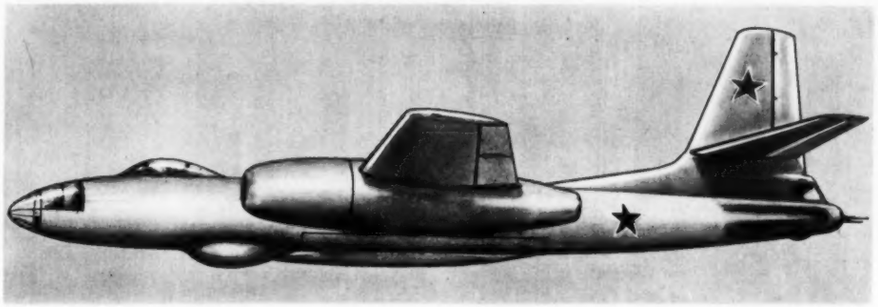
service in any numbers with the strategic air fleet is an open question.

Russian Air Force equipment still covers a limited range of aircraft types, the number of which is strikingly small compared with Western air forces' type lists (see table on next page).

American and British observers estimate that the Russian Ministry of Aircraft Production controls more than 350 plants, of which 80 are believed to be concerned with airframe production and about 30 with engines. The remainder are equipment and accessories plants. Returning prisoners of war have confirmed that new production plants in the Leningrad, Gorki, Kazan, Saratov and Rostov areas are in every way equal to modern installations in the Western aircraft industries.

With the exception of the Central Aerodynamic and Hydrodynamic Institute (Z.A.G.I.), Z.I.A.M. and a number of institutes under the Ministry of the Armed Forces, all aeronautical research centres are attached to the Ministry of Aircraft Production. Most of the aircraft design offices are grouped together in a central directorate with headquarters in the Z.A.G.I. premises in Moscow. A number of design offices have been identified as being under the control of Lieutenant General Sergei A. Ilyushin, Lieutenant General Andrei N. Tupolev, Lieutenant General Semion A. Lavochkin, Colonel General Alexander Sergievich Yakovlev and Major General Artem I. Mikoyan. The initials of these names provide part of the type designations of the best-known Russian aircraft. Other well-known designers are Petliakov, Bratushin, Shcherbakov, Sukhoi, Cheranovski and Antonov.

The Russian aircraft industry's design offices have a number of wind tunnels at their disposal for model investigations. These include three tunnels at the Moscow-Tushino test centre, two high-speed tunnels at Ramenskoie and a supersonic tunnel on Z.A.G.I.'s premises.



The Tu-12 is in service with the Russian naval air units in the Far East for detection and attack of naval targets.

Then there are pure research wind tunnels at Moscow-Ramenskoie, Leningrad, at the test centre on Lake Velikoie near Kalinin, and elsewhere. The Joukowski Academy for Aeronautical Research runs a wind tunnel in Moscow and another at the University of Kazan. Equipment and instrumentation for new aircraft types are as a rule planned by a special section of Z.A.G.I.

Unlike the actual design offices, the government research institutes have extensive experimental installations. For example, the Central Aerodynamic and Hydrodynamic Institute in Moscow is fully equipped to build prototypes. In 1940 this plant employed about 12,000 workers. By 1950 this figure had risen to nearly 20,000. The "Gorki" experimental plant on the same site has also considerably increased its staff since the end of the war. To judge by the size of their shops, the prototype of a long-range four-jet bomber shown at the 1954 May Day Parade may well have been built by one of these two plants.

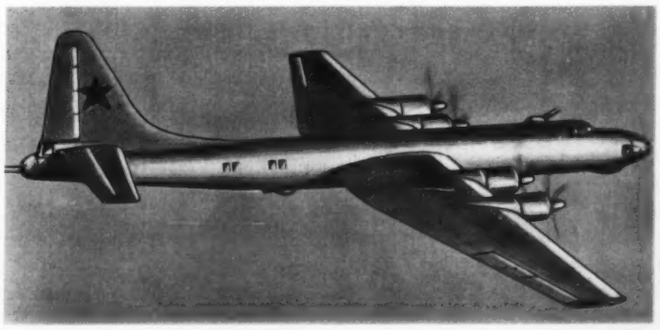
The Red Air Force's fleet

There is today less uncertainty about the aircraft used by the Red Air Force than there was five years ago, though technical details of the various types—with the exception of the MiG-15—are still not known. From time to time fragments of information on dimensions or engine power, together with photographic material, enable performance to be estimated, but give no useful indication of flying behaviour or combat serviceability.

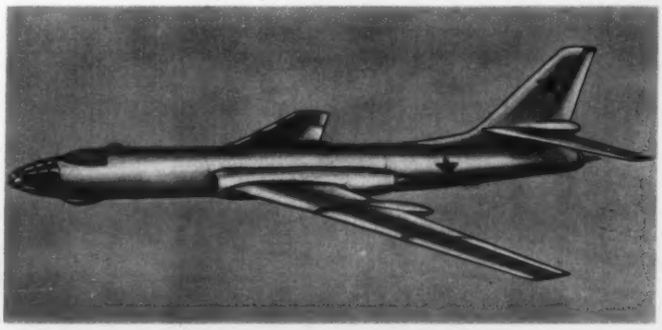
The number of *MiG-15* variants so far known shows that the principle of a versatile standard fighter cannot meet all requirements for day and night fighter operations. As a result, other types—such as *Il-28* and *Il-28-2* tactical bombers converted for use as all-weather fighters—appeared in East Germany three years ago. — The *MiG-17,* developed from the *MiG-15,* is a pure interceptor fighter, and it looks as if the Russians have decided to abandon the idea of a general-purpose fighter. Experience in Korea was probably a deciding factor here. A striking feature in the *MiG-17,* compared with its predecessor, is its higher aspect ratio and larger rudder unit. These measures recall recent modifications to the North American F-100 *Super Sabre,* which were found to be necessary in order to reduce roll and yaw tendencies in the near-sonic range.

A *delta-wing fighter* designed by *Cheranovski,* some scant data on which have recently leaked out, displays certain similarities to American and British all-weather fighters (Convair F-102 and Gloster *Javelin*), but unlike these models has large leading edge flaps to improve maximum lift, always inadequate in delta wings.- For some time past a *twin-jet "flying-wing" fighter* with sharply swept wing has been observed on the ground and in flight in the Moscow area. It is allegedly for all-weather use.

Originally the TuG-75 four-engined long-range bomber was powered by diesel engines, but later models are said to have Junkers propeller turbines.



Highlight of the Red Air Force's 1954 May Day Parade was the fly-past of nine ZAGI-228 twin-jet long-range bombers (N.A.T.O. code name *Badger*).



Russian Type Designation (N.A.T.O. code name in brackets)	No.	Power Plant: Category	Power Plant: Type	Power Plant: Static thrust lbs.	Span ft. ins.	Length ft. ins.	Gross weight lbs.	Max. speed m. p. h.	Remarks
Fighters									
MiG-15 (Falcon)	1	Radial jet	RD-45	5,785	33' 1½"	36' 4"	11,270—14,240	670	Red Air Force standard fighter; armament: two 23-mm cannon Type NS and one 37-mm cannon; rate of climb near ground 10,400 ft./min.; service ceiling 50,800 ft.
MiG-15 bis	1	Radial jet	VK-1	5,955	33' 1½"	36' 4"	11,085	690—720	Improved version with more powerful engine, modified equipment and perforated landing flaps.
MiG-15 F	1	Radial jet	RD-45 F*	5,955	34' 6"	40'	app. 13,600	690	Two-seat all-weather fighter with longer fuselage, rounded wing tips and lower set elevator unit; radar aerial in fuselage nose above air intake.
MiG-17 (Fresco)	1	Radial jet	—	—	34' 6"	37' 8"	app. 13,200	750+	Development of MiG-15; features more sharply swept wings with total of six boundary layer fences, higher aspect ratio and modified rudder unit.
Super-MiG	2	Axial jet	—	app. 6,600	app. 43'	app. 43'	22,000—26,500	750+	Twin-jet two-seat all-weather fighter; observed in formation flight over Moscow-Tushino in 1952 and since confirmed by several sources.
Cheranovski delta-wing	1	Axial jet	Mikulin 205*	10,000	app. 46'	app. 39'	26,500—31,000	690—750	Single or two-seat all-weather fighter; derived from a series of experimental types with different arrangements of engines and rudder units; cannon in wing roots and search radar in nose.
Twin-jet all-weather fighter	2	Axial jet	Mikulin 205*	10,000	app. 46'	app. 39'	26,500—31,000	690—750	Flying-wing design of interesting aerodynamic configuration; unlikely to be in service in quantity.
Yakovlev fighter flying boat	2	Axial jet	Mikulin 205*	10,000	app. 46'	app. 39'	app. 26,500	625—690	Prototype designation P. 57; probably designed for service with the Russian Naval Air units in the White Sea and Baltic areas and the Far East; having undergone extensive flight testing, may be in production.
La-17	1	Radial jet	RD-45	5,785	40'	36'	app. 14,300	635	Escort fighter and ground attack aircraft; standard armament: two large-calibre cannon beneath air intake; developed at about same time as MiG-15, but has only been observed in small numbers.
Yak-21	1	Rocket	Development of HWK-509	4,400+	31' 2"	26'	app. 12,000	655	Local defence fighter with cannon and armoured nose, developed from Me 263; rate of climb more than 16,000 ft./min.
Bombers									
Il-10 (Beast)	1	12 cyl. in-line	AM-42	2,000 h. p.	45'	39'	app. 15,000	290	Two-seat ground attack and close reconnaissance aircraft. Developed from the successful Il-2 *Stormovik*, this robust armoured low-wing monoplane is still in service with the tactical units in Russia and the satellite countries.
Il-28 (Butcher)	2	Radial jet	RD-45	5,785	app. 72'	app. 65' 6"	44,000—48,500	600	This twin-jet bomber has been standard equipment for the tactical units for some years; armament: two heavy machine guns in manned rear position and 2 fixed cannon under the nose.
Il-28-2	2	Radial jet	VK-1	5,950	app. 72'	app. 72'	48,500—52,800	625	Development of the Il-28 with swept wing; a night fighter version with modified armament and search and navigation radar has been observed for some time in East Germany.
Tu-12 (Bosun)	2	Radial jet	VK-1	5,950	app. 82'	app. 79'	app. 55,000	550	Navy tactical jet bomber, primarily for detection and attack of naval targets.
EF-150	2	Axial jet	Mikulin 205 or Lulkov 4	10,000 11,500	95'	93' 6"	116,500	655	Jet bomber developed by Junkers engineers. Range with a bomb load of 8 tons roughly 2,200 miles; crew of 4; armament: 2 × 23-mm cannon in retractable turret on top of fuselage, 2 × 23-mm NS cannon in fuselage rear and two fixed cannon in nose.
ZAGI-228 (Badger)	2	Axial jet	Lulkov 4*	11,500	app. 98' 6"	app. 105'	app. 130,000	Ma 0.9 at 43,000—50,000 ft.	First shown at 1954 May Day Parade; will probably be in service with the long-range bomber fleet in limited numbers before the end of the year.
ZAGI-428 (Bison)	4	Axial jet	Lulkov 4*	11,500	app. 158'	app. 150'	app. 265,000	Ma 0.9 at 43,000—50,000 ft.	The aerodynamic configuration of the prototype, shown at last year's Parade, suggests high speed. Probably not yet in full-scale production.
Tu-4	4	18 cyl. radial	Ash-90	2,500 h. p.	141' 5"	99' 5"	132,000—143,000	360	Copy of Boeing B-29.
TuG-75	4	Turboprop or Diesel	Jumo 022 Jumo 224	3,000 s. h. p. +1,000 or 4,500 h. p.	app. 180'	app. 138'	220,000+	400 at 27,000 ft..	Probably built in small numbers for the long-range bomber fleet.
Unconfirmed types									
CZ-2B	2	Axial jet	—	—	42'	54'	22,000—26,000	—	Polish-Russian project for a V.T.O. fighter with two turbojets.
Il-38	4	Turboprop	—	—	app. 115'	app. 105'	app. 150,000	550+	Existence of this long-range bomber has not yet been confirmed; it is unusual for a turboprop bomber to have so marked a wing sweep.
Tu-200	6	Turboprop	—	—	app. 180'	app. 148'	app. 265,000	550+	Rumours of a Red Air Force inter-continental bomber first appeared in 1950 and 1951, but no reliable information is available on this type, which resembles the Convair B-36.
Type 480	8	Axial jet	—	—	app. 180'	app. 144'	app. 265,000	625+	A feature of this eight-jet long-range bomber is the suspension of the engines in pods, as in the Boeing B-52 *Stratofortress*.

* Unconfirmed

Reports on a *jet-powered fighter flying boat prototype,* designed by A. S. Yakovlev and designated P.57, began to appear some months ago. Water take-offs and flight tests were made by three such aircraft near the Magadan I White Sea base between March 1953 and February 1954. The P.57 project is unconventional in both structure and appearance, and differs markedly from Yakovlev's earlier designs. The squat-looking flying boat is fitted with two axial-compressor engines above the wing roots, which are said to give a speed of over 620 m.p.h. The wings are swept back 40° and each has two boundary layer fences on its upper surfaces. The upper portion of the fuselage probably houses radar equipment. The flying boat may also have an undercarriage for use on land.

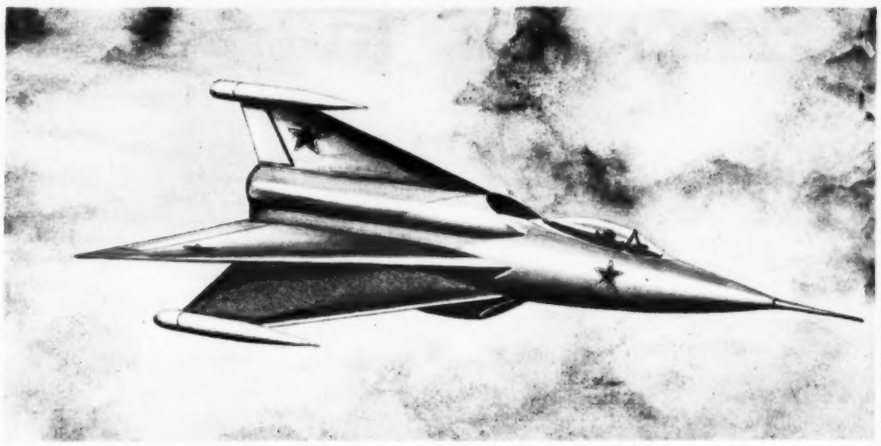
The existence of a *Yak-21 rocket fighter* (with liquid-propellant rocket engine) has been confirmed by a number of prisoners of war returning from Russia. As the military value of such fighters is debatable, however, it is doubtful whether development of the type has been continued.

The *Tu-12* was the first jet-powered tactical bomber to go into service in quantity. The design goes back to 1947 and appears—to judge from its aerodynamic configuration—to have been influenced by the *Convair XB-46.* A number of pre-production models made their début at the 1948 May Day Parade. Designed primarily for use against naval targets, this aircraft has been in service for some time with the Red Air Force's Far East units. The twin-jet bomber's slender fuselage has a long bomb bay, in which torpedoes can be stowed. The arrangement of the gun positions varies in the different versions. As a rule there are two turrets containing twin machine guns, while all versions carry a fixed cannon on either side of the fuselage. Isolated aircraft have also been observed with radomes underneath the fuselage.

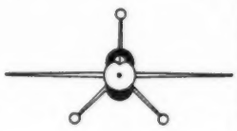
The Tupolev jet bomber was followed into service by the *Il-28.* Evidently designed to a similar, if not the same, specification as the *Tu-12,* this twin-jet model is in use by the Army's tactical air units and a further development, with swept wing, has been seen in the Russian zone of Germany for about the past three years. There are several versions of the latter type, often designated as the *Il-28-2,* one of them being a night fighter.

The *EF-150* designed by Junkers engineers will probably not now go into production.

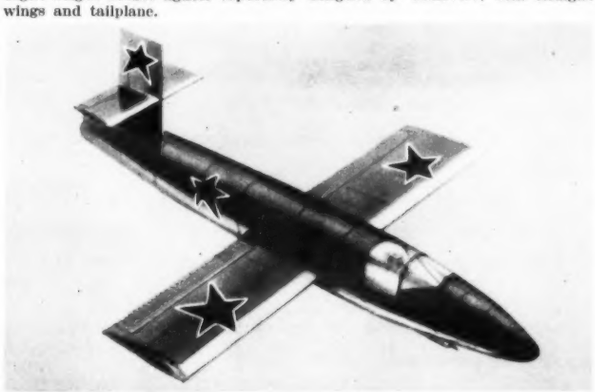
Unconfirmed Russian Aircraft

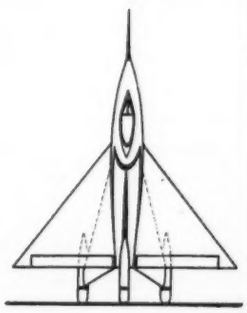


Polish-Russian design for a vertical take-off fighter, the CZ-2B, with two turbojets. *Right:* general drawing.

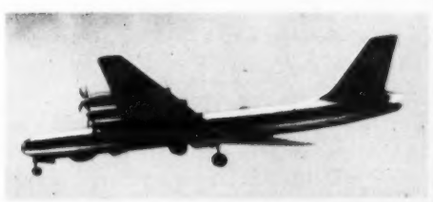


Light-weight rocket fighter reportedly designed by Yakovlev, with straight wings and tailplane.

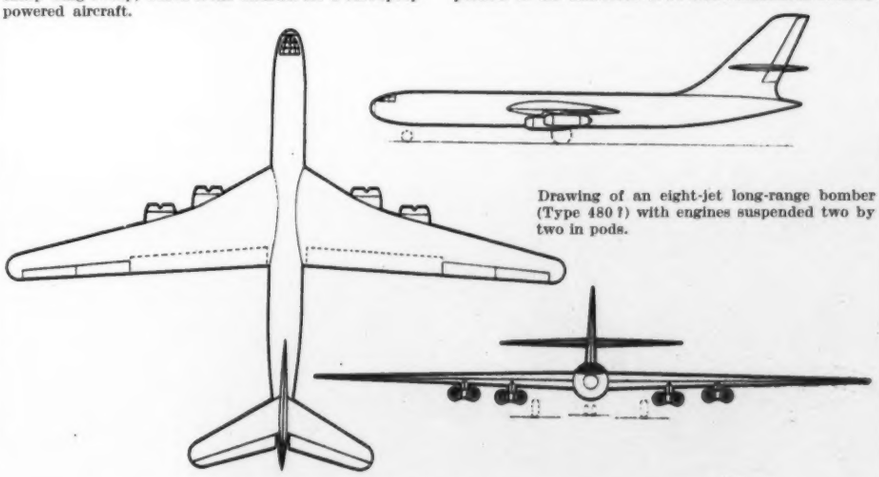




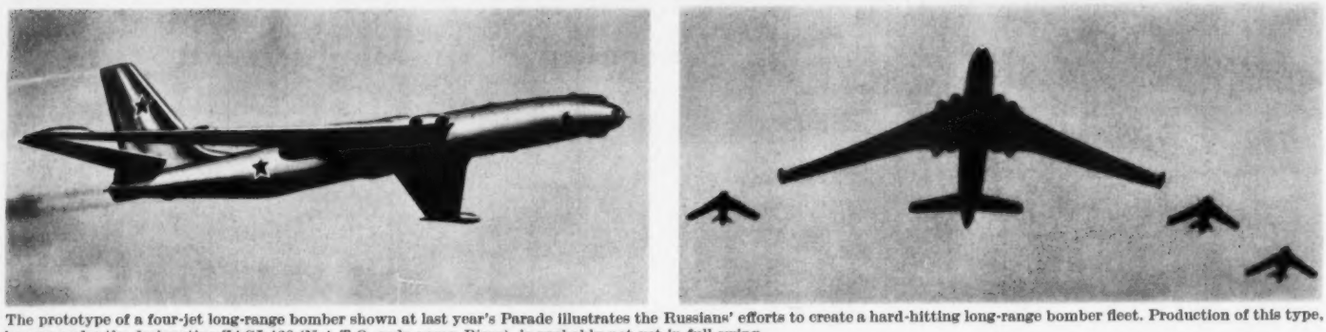
The long-range bomber known as the Il-38 has a strikingly sharp wing sweep, which looks unusual for a turboprop-powered aircraft.



The Tu-200 with its six propeller turbines would be comparable to the American B-36 intercontinental bomber.



Drawing of an eight-jet long-range bomber (Type 480 ?) with engines suspended two by two in pods.



The prototype of a four-jet long-range bomber shown at last year's Parade illustrates the Russians' efforts to create a hard-hitting long-range bomber fleet. Production of this type, known under the designation ZAGI-428 (N.A.T.O. code name *Bison*), is probably not yet in full swing.

Two prototypes, both used only for experimental purposes, had been built by 1951.

The climax of the 1954 May Day Parade was the fly-past of two new long-range bomber types, to which N.A.T.O. has given the code names *Badger* and *Bison*. Nine *Badgers* flew past in quick succession, apparently to give the impression that this type is already in quantity production. The main features of the twin-jet *Badger* are a slender 35° swept wing, large engine nacelles on either side of the fuselage centre portion, undercarriage cowlings projecting beyond the leading edge of the inner wings, and a manned gun position in the fuselage rear. The installation of the two jet engines near the fuselage centre line offers the advantage of an aerodynamically undisturbed wing, and the reduced drag thus obtained doubtless plays an important part in increasing range. If the *Badger* belongs roughly to the same performance class as the Boeing B-47 *Stratojet*, the four-jet *Bison* probably corresponds more closely to the Boeing B-52 *Stratofortress* inter-continental bomber. It is not very likely, however, that the Russian long-range bomber fleet has any considerable number of these aircraft yet. Like the *Badger*, the *Bison* also has a 35° swept wing of high aspect ratio, and jet engines buried in the wing roots. In both types the length of the engine cowlings is striking.

Long-range bombers could not be built in the Soviet Union until reliable high-power jet engines were available. The Mikulin and Lulkov gas turbines now used are said to be more powerful than America's biggest jet engines.

Even pure speculation may sometimes prove correct, so the present list also includes four unconfirmed Soviet aircraft types. The most revolutionary in aspect is the Polish-Russian "design" for a V.T.O. fighter with delta wing. Two other types, with propeller turbines, which were discussed under the designations *Il-38* and *Tu-200* in *Interavia* No. 4, 1954, may probably be regarded as authentic. The Type 480 included at the end of the list is an eight-jet long-range bomber with a span of more than 165 ft. An interesting point is the suspension of the jet engines in pods underneath the wings, as in the American B-52.

An American Antidote to Enemy Atom Bombers

No fewer than 104 2.75-inch air-to-air rockets with folding fins are carried by the Northrop F-89D *Scorpion* twin-jet all-weather two-seat fighter. The rockets are housed in two pods at the wing tips and are fired automatically in groups or volleys. Electronic aiming equipment in conjunction with radar sighting enable the fighter to get into best firing position even when the enemy is not visible. Picture shows the rocket complement (52) for the port container only; the fighter carries no cannon. Power plant for the F-89D: two Allison J-35-A-35 turbojets of 5,600 lbs. static thrust each plus Solar afterburner.

The Aerodynamic Laboratory at Vernon

BY CHIEF ENGINEER P. CARRIÈRE, VERNON, FRANCE

Shortly after the end of the war the *Direction des Etudes et Fabrications d'Armement* decided to construct a new research centre for ballistics and aerodynamics near Paris. The new centre was to have three main sections : 1.— guidance ; 2.— propulsion ; 3.— aerodynamics.

When the plans were completed (in 1947) a wooded site at Vernon on the right bank of the Seine was selected for the centre. So arose today's *Laboratoire de Recherches Balistiques et Aérodynamiques.*

Building was begun in November 1948, and the 20,000 h.p. supersonic wind tunnel, one of the aerodynamic section's show pieces, was taken into service on June 9th, 1952.

*

The following is a brief description of L.R.B.A.'s aerodynamic test equipment : chief items are :

— a 16×16-inch supersonic wind tunnel with closed circuit (20,000 h.p.) for continuous operation ;

— three smaller supersonic wind tunnels with open circuit, for intermittent operation ;

— a ballistic firing range 365 ft. long, with photographic measuring equipment.

The above are completed by a large number of auxiliary installations, such as workshops and store-rooms, laboratories for measuring instruments, etc.

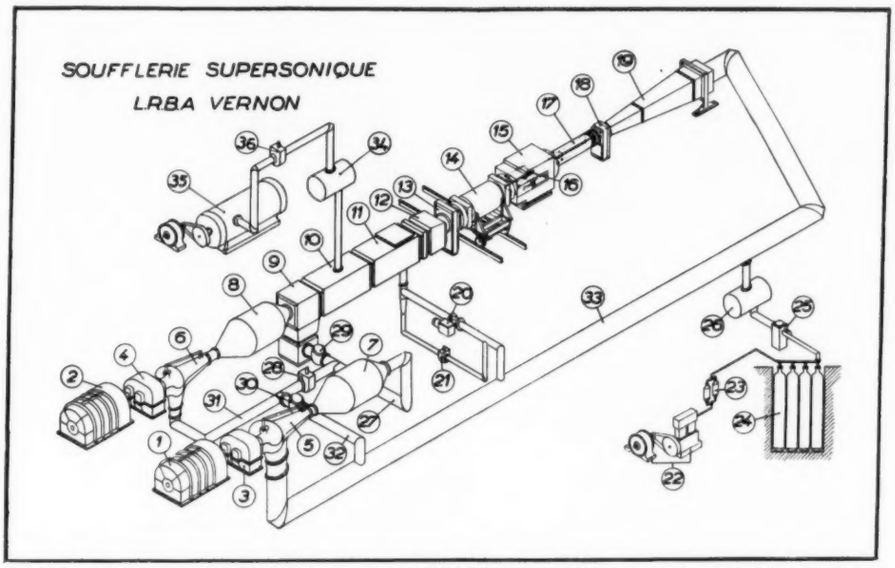


Fig. 1 : Supersonic wind tunnel with closed circuit at the L.R.B.A., Vernon : 1 and 2- electro-motors ; 3 and 4- gears ; 5- low; pressure blower ; 6- high-pressure blower ; 7 and 8- air coolers ; 9- mixing chamber ; 10 and 11- compensating chambers - 12- convergent nozzle ; 13- regulator ; 14- exchangeable front portion with Laval nozzle ; 15- test chamber ; 16- measuring equipment ; 17- adjustable divergent nozzle ; 18- regulator ; 19- fixed diffusor ; 20- by-pass valve ; 21- regulating valve ; 22- compressor ; 23- air drier ; 24- compressed air flasks ; 25- pressure reducer ; 26- compressed air container ; 27- pipe ; 28- regulator ; 29 and 30- blocking valves ; 31 and 32- pipes ; 33- return pipe ; 34- vacuum tank ; 35- vacuum pump ; 36- regulator. — In "series operation" valves 29 and 30 are closed, while regulator 28 is open ; in "parallel operation" the reverse is the case.

The large supersonic wind tunnel

This closed-circuit tunnel *(fig. 1)* is continuously supplied with air by two Brown-Boveri axial blowers, driven by electro-motors, with a total power of 20,000 h. p. The two blowers can work either in series or in parallel. Pressure can be regulated within wide limits, and the air is thoroughly dried in an air-conditioning plant. Main data :

— Mach number : 1.5 to 4.4 (soon from 1.35)

— air pressure in front of test section : 14-160 p.s.i. (1 to 11 kg/cm²)

— humidity : less than 1 gramme of water per kg of air (normally 0.2 to 0.5 gr/kg, corresponding to a dew point of —31°C to —22°C)

— air temperature in front of test section : 20°C to 50°C.

— test section : 16×16 ins. (40×40 cm).

Special attention has been given to *eliminating all vibrations*, in particular by separating the machine room from the test room. The test section itself stands on a large concrete foundation insulated from the rest of the building, and is connected with the air feed system by elastic joints. All controls and reading instruments are housed centrally in a sound-proof control room, so that the staff is also protected from noise and vibration *(fig. 2)*. It may also be mentioned that the scientist in charge of the experiment has the *stria picture of the flow* constantly in front of him on a special screen.

Fig. 2 : Control room of the closed-circuit (large) supersonic tunnel during a test.

Fig. 3 : Changing the front portion of the closed supersonic tunnel by means of sled and travelling crane.

Fig. 4 : View (from the other side) of the test chamber of the closed supersonic wind tunnel. The chamber has a section of 16×16 ins.

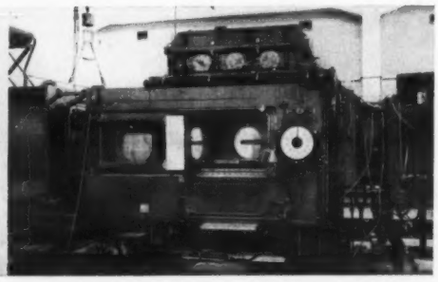


Fig. 6 : Serial photograph of a " free-flying " model in the vertical open tunnel, according to Engineer Auriol's method, at Mach 2.14.

The test section is of very original design. The principle followed is that of using fixed adapted nozzles for each given Mach number, and arrangements have been made for rapidly changing the nozzles. The actual test chamber is relatively large and has round glass windows in the sides. The Laval nozzle for the desired Mach number is introduced into the test chamber from the front, with the whole of the portion in front of the chamber being changed at the same time. The old and new portions can be moved longitudinally or sideways on a double sled on rails and can be raised or lowered into " reserve position " by a travelling crane *(fig. 3)*. Two pneumatic packings ensure airtight fit.

If the nozzle required for the subsequent test is placed on the sled beforehand, the whole process of changing takes only three minutes. — The test chamber also contains the *test table*, whose angle of incidence to the flow can be varied, and which carries the test model, measuring equipment, manometer connections and electric plugs *(fig. 4)*.

Pressure in the wind tunnel can be adjusted as required, either by adding fresh dry air or by removing air from the tunnel. An automatic regulating system (by-pass leads 20 and 21) ensures maintenance of the desired pressure during the test, with an acuracy of 1 to 2 mm Hg.

The *air temperature* can also be regulated, by varying the amount of water led to the air coolers. The required temperature behind each of the two blowers can be set within two minutes and is maintained within $\pm 0.25^{o}$C.

As regards *Reynolds Numbers*, which are of decisive importance in many aerodynamic investigations concerned with the nature and thickness of the boundary layer, it is possible to examine the same model in the laminary region and in the turbulent region. For conventional profiles the Reynolds Number for the transition from laminar flow to turbulence is between 4×10^6 and 6.5×10^6.

Air humidity is checked by a self-recording sulphuric acid hygrometer which detects variations of a hundredth of a gramme of water per kg of air (in the test section 0.1 — 3 gr/kg) within ten seconds.

A *recording system* made by Société Bélin enables the readings of all instruments, up to 175 digits, to be collected immediately. These values are then (within 25 seconds) written down in clear and simultaneously transferred to punched cards. The latter are evaluated in a Gamma 3 Bull computer.

Test equipment available includes :

— automatic pressure balance, to ascertain pressure in front of the test model ;

— multiple manometer for mercury, alcohol and other measuring fluids ;

— pressure capsules for electro-magnetic readings of very small pressures (with an accuracy of ± 0.05 mm for 0-5 mm Hg) ;

— balances with electrical strain gauges.

*

The large Vernon wind tunnel's well-designed equipment makes it particularly suitable for rapid accurate work. For example, up to 16 polars of a model can be measured in four different conditions and at four different Mach numbers in eight hours, with each polar showing 22 measuring points for angles of incidence between —6° and +15°. The personnel required is one engineer and not more than eight assistants.

Fig. 5 : Two of the three open supersonic wind tunnels for intermittent operation : test section 8×8 ins. ; the rear tunnel is vertical.

The small supersonic wind tunnels

In addition to the large wind tunnel, several smaller supersonic tunnels with open circuit were considered to be necessary, in particular to enable preliminary investigations on missile projects to be carried out economically. Here the principle of intermittent flow, first successfully tried by *Langevin* and *Huguenard* in 1916, has been applied.

A group of tanks totalling 12,500 cu.ft. capacity, that can be emptied of 99% of their air by 200 h.p. pumps within three minutes, serves as *vacuum level*. Attached to the tanks are three test sections (cf. *fig. 5*), through which *atmospheric air* flows into the empty tanks. Each of the test sections has a quick operating valve, which can be opened or shut within 0.2 seconds, as well as an exchangeable Laval nozzle and diffusor. A silica-gel container at the entrance to the test section dries the air, which flows through at the rate of approx. 22 lbs/sec, reducing its humidity to 0.2 grammes of water per kg. Thus, as soon as the valve is opened, air flows into the test section in an accurately defined thermal state. Each flow process lasts only 30 to 45 seconds, but this short period of time fully suffices for all conventional measurements.

With this installation up to 90 measurements a day can be made. The Laval nozzles have an entry area of 8×8 ins. ; their Mach numbers are the same as for the large tunnel. Only three persons are needed for each measurement.

*

One of the three test sections is a vertical one (cf. *fig. 5* ; background). This enables the very original test technique for small supersonic bodies proposed by Engineer *Auriol* to be applied. As soon as the air flows at full speed through the test section, the model is projected *upwards* into the test section, against the direction of flow. The model's own speed is only a few metres a second, but is sufficient to provide measuring periods, between " rise " and " fall ", of about 0.2 seconds in regular flow.

During this very short period of time something like 40 flashlight photographs can be taken, which provide an accurate picture

of the model's ballistic behaviour (cf. *fig. 6*). The missile's drag coefficient is then obtained by calculation, with an accuracy of 1%. As the measurements are also made as if in free flight, no corrections need be made for supports, etc. The new test method appears to be particularly suitable for comparisons with aerodynamic measurements in the firing tunnel. Presumably it will also be possible to ascertain other aerodynamic coefficients (e.g. lift, longitudinal and rolling moment, etc.) by this means.

The central air-conditioning plant

As both the closed-circuit (large) supersonic tunnel and the open-circuit (small) tunnels need conditioned air, a central *air-conditioning plant* was installed. This plant comprises :

— three vacuum pumps for the open wind tunnels' group of suction tanks ;

— silica-gel driers for the outside air flowing into each of the three open tunnels ;

— five piston compressors for 3,550 p.s.i. max. pressure, and a drying installation.

The piston compressors supply air dried to 0.02 gr/kg. to a battery of 32 compressed air flasks with a capacity of 35 cu.ft. each at a max. pressure of 3,550 p.s.i. The battery feeds the closed tunnel with air at up to 355 p.s.i. pressure. The closed tunnel is also connected by a pipe to the suction tanks of the three open tunnels, so that if necessary it can also be used to empty these tanks. Finally the compressed air flasks can also be connected direct to one of the open tunnels, so that extreme Reynolds Numbers can be obtained for special tests (blow-down tunnel).

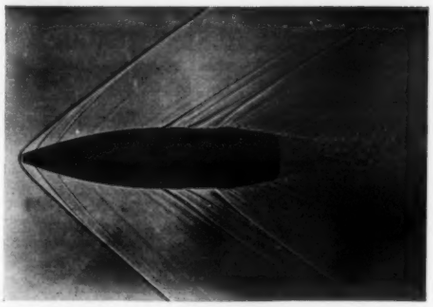


Fig. 8 : Photograph of a free-flying projectile in the firing tunnel.

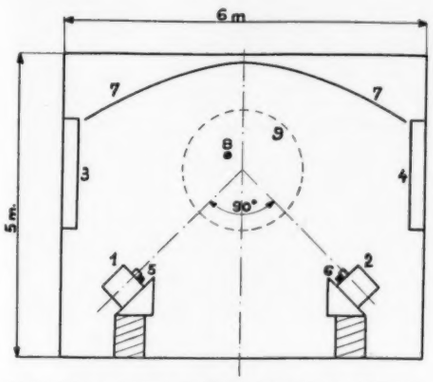


Fig. 7 : Section through the 365-ft. firing tunnel at Vernon. 1 and 2- cameras ; 3- optical barrier ; 4- photo-electric cell ; 5 and 6- high-intensity flashlight ; 7- reflector ; 8- free-flying projectile ; 9- dispersion circle of trajectory.

The firing tunnel

For free flight aerodynamic tests there is a 365-ft. firing tunnel with a section of 16.4 × 19.7 ft. (cf. *fig. 7)* with a 65.5-ft. wide observation room (with firing platform) at one end. The tunnel is equipped with photographic apparatus for high-intensity flash-light exposures, which take pictures of the model in flight in rapid succession. The aerodynamic drag coefficients of the model can then be calculated from these photographs by " ballistic methods ". *Fig. 8* shows a picture taken in the firing tunnel.

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At present the aerodynamic section of the Vernon research centre works primarily for the Directorate of Armament Research and Production on the latter's special programmes, though with its modern equipment it is also capable of carrying out research contracts for other agencies, in particular the aircraft industry.

Fire Control Systems

By Lieutenant-General D. G. H. Brethouwer, Director, N. V. Hollandse Signaalapparaten, Hengelo, Holland

General

A fire control system is a combination of instruments enabling a weapon or group of weapons to be directed in such a way that their projectiles will hit the target. The following weapons are usually provided with fire control systems :

— guns,
— rocket or missile launchers,
— torpedo launchers.

Fire control systems for guns : As *guns* are used to fight surface and air targets, the corresponding fire control systems are called *low-angle* or *anti-surface fire control systems* in the former case and *anti-aircraft* or *high-angle fire control systems* in the latter. Sometimes the gun has to be used against both surface targets and aircraft, in which case the corresponding fire control system is called *combined anti-aircraft/surface fire control system.*

Guns are used ashore, at sea, or in the air. In the latter case the fire control system is called *air-to-air fire control system.*

Fire control systems for rocket or missile launchers : Rocket launchers are used to launch rockets or missiles against air targets, surface targets or sub-surface targets. They are mounted in aircraft, aboard ships and ashore. The fire control systems connected with these weapons carry similar names to those used for the corresponding gun systems, with a possible exception that the word " rocket " or " missile " may be added, for example, *anti-aircraft missile fire control system.*

Principle and arrangement

The basic principles for all types of fire control systems are similar, the object being to calculate the point, either in space, on land, at sea or below the surface, where projectile and target are to meet.

The system must therefore determine the coordinates of the present position of the target accurately. Course and speed of the target are determined from the rate of change of these coordinates and are then used to calculate the future position where target and projectile are to meet. Lastly the equipment translates the coordinates of the future position into the positioning angles for the gun or launcher.

Although the overall characteristics of the various systems are similar, it goes without saying that the actual arrangements of the systems differ considerably, because of the difference in speed between a sub-surface target and an air target, between the gun projectile and the torpedo, etc.

A fire control system consists basically of the following parts :

I — A part to determine the position of the target.

II — A part to determine course and speed of the target.

III — A part to predict the future position.

IV — A part to transmit position angles to the launcher or gun.

The means of determining the position of the target vary with the nature of the target. The coordinates of air targets for instance, are usually determined by means of gunnery or *tracking radar* (cf. *Fig. 1*). The coordinates of surface targets at sea are determined by radar, although optical aiming still exists. The position of under-water targets, however, can only be determined by means of echo sounding equipment.

Course and speed of a target are measured from the rate of change of the coordinates of the target. It will be clear that it is essential to determine course and speed with a very high accuracy. If, for example, the speed of an air target flying at 250 m/sec were miscalculated by 2.5 m/sec, the error in prediction, from wrong speed measuring alone, would be 50 metres for a time of flight of 20 sec.

In anti-aircraft systems speeds are measured by direct differentiation of the continuously changing position data (cf. *Fig. 2*). Tracking of air targets is continuous. Preferably it is carried out by radar, operating automatically. This tracking must be very smooth, which means that jitters and fluctuations must be effectively damped out, at the same time, however, taking special precautions that accuracy is not impaired.

The *computer* calculates the geometrical position in space where projectile and target are to meet. In order to position the gun or the launcher so that the projectile will hit the target, the geometrical coordinates of the future position must be transformed into positioning coordinates. Moreover, in the case of gun or rocket fire control systems, certain meteorological factors have to be taken into account, to compensate for their effect on the projectile during its flight. This conversion is carried out in the ballistic corrector which sometimes forms an integral part of the computer. The computer also takes into account the parallax distance between the aiming part of the system (radar, for instance) and the weapon. For equipment on shore, this distance is usually much larger than for ship or airborne equipment.

Radar equipment for fire control

Radar is an integral part of any anti-aircraft or anti-surface fire control system and replaces visual aiming and range measuring in most cases. It not only enables the equipment to be used over much longer ranges, but also enables the system to be operated at night as effectively as in day time.

In order, however, to be able to direct the radar to the target it is necessary to detect this target well outside the range of the tracking radar. This detection process naturally also has to be accomplished by means of a radar system called a *search or warning radar*.

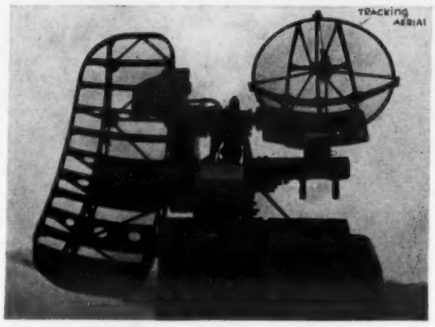


Fig. 1 : Aerials (and reflectors) for the combined anti-aircraft radar gun fire control system made by N.V. Hollandse Signaalapparaten, left, for the acquisition radar ; right, for the tracking radar.

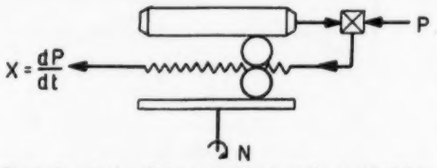


Fig. 2 : In anti-aircraft fire control systems the speed of the target is calculated by direct differentiation of the observed coordinates : P = incoming value ; N = constant speed.

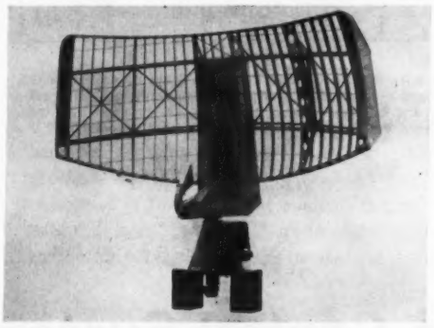


Fig. 3 : Long-range warning radar.

Fig. 4 : N. V. Hollandse Signaalapparaten's complete fire control system for anti-aircraft guns, on two trailers.

Radar systems, both ashore and aboard ship, are usually divided into three categories :

— warning radar,

— acquisition or target designation radar and

— tracking radar.

Warning radar is used to detect the presence of a target (cf. *Fig. 3*). The acquisition or designation radar (cf. *Fig. 1*) is a link between the warning and the tracking radar. The warning radar may be used for other purposes than weapon direction, for example, for aircraft interception with fighters. Acquisition or designation radar is used solely to direct the tracking radar towards the targets.

Stabilization of fire control equipment

Although the fundamentals of the fire control problem ashore and aboard ship are similar, the arrangement of the system aboard ship is more complicated owing to the fact that both aiming and weapon laying must be carried out on a moving deck.

Radar and other aiming equipment are therefore provided with *stabilization equipment* to enable them to measure target position without being influenced by the ship's motion in any direction. The same is true for the position angles which are transmitted from the computer to the gun or launcher.

Stabilization is usually by means of gyroscopes, which measure the ship's roll, pitch and yaw. These angles are transmitted to various fire control systems, where they are converted into the appropriate data for the aiming of the gun and weapon laying systems.

Military and technical characteristics

The military and technical characteristics vary with the specific targets or due to the fact that one equipment is to be used ashore, whereas the other will be used aboard ship. Again another equipment may have to be put in a well-protected concrete coastal position. All systems, however, have one thing in common : they have to occupy as little space as possible. This is naturally true aboard ship, but also ashore where, because of the mobility of modern warfare, they have to be put in trailers and the like.

For shore equipment it is important that the units which have to be linked up should be placed close together in order to avoid long connecting cables. Therefore efforts are made to combine various units wherever possible.

*

A very good example of this is the *complete anti-aircraft radar gun fire control system manufactured by N. V. Hollandse Signaalapparaten*, shown in *Fig. 4*. This fire control system *not only tracks a target*, but *can also detect targets*. The radar aerials which are used for this purpose are combined into one instrument, which moreover, enables one man to operate the system in an emergency with the help of binoculars.

The computing system is housed in the small two-wheeled trailer shown in the photograph and can be used to direct as many as six guns, with full automatic remote control.

What's in the Air ? *

AVIATION POLITICS

● Intensification of American security measures

Measures aiming at more stringent control of the release of military information have been adopted by Defense Secretary Charles E. Wilson. When writing contributions for the press, military writers are forbidden to use information not generally accessible, and all contributions by military persons must be cleared by the U.S. Defense Department prior to publication. The public relations staffs of the Army, Navy and Air Force Departments will be cut by from 30 to 50 %, and military members replaced by civilians.

● No atomic weapons for Sweden

During a debate on defence allocations, Swedish Defence Minister Nilsson stated that " Sweden does not plan either to import or to manufacture atomic weapons." The statement contradicts reports circulating in the Swedish press that Sweden was considering the production of atomic weapons.

SERVICE AVIATION

● Strength of the Strategic Air Command

At a ceremony held at Offutt AFB, Omaha, to mark the ninth anniversary of the U.S. Air Force's Strategic Air Command, Commanding General Curtis E. LeMay stressed his conviction that the continuity of U.S. strategic air power will determine " the difference between peace and war for many years to come." — At present the S.A.C. comprises 25 wings of 45 Boeing B-47 *Stratojets* each and 30 wings of ten Convair B-36s each (the latter's six piston engines have recently been supplemented by auxiliary turbojets at the wing tips, so that take-off weight and operating altitude have been considerably increased). The bombers are protected by an undisclosed number of Republic F-84F *Thunderstreak* fighters and Republic RF-84F *Thunderflash* reconnaissance fighter-bombers. First deliveries of the B-52A *Stratofortress* eight-jet long-range bomber are expected this spring. Ultimate goal is a force of 2,000 to 3,000 long-range bombers.

Professor Theodore von Karman (right), who has resigned after ten years as Chairman of the U.S. Air Force Scientific Advisory Board in order to devote himself entirely to his duties as Chairman of N.A.T.O.'s Advisory Group for Aeronautical Research and Development, has been presented with the Exceptional Service Award, the U.S.A.F.'s highest award to a civilian. The presentation was made by Trevor Gardner, Assistant Secretary of the Air Force for Research and Development, at a plenary session of the Advisory Board.

● Dutch call for suitable all-weather fighters

The Dutch Army periodical " Ons Leger " describes the absence of suitable all-weather fighters as a " serious gap in the Dutch defence system ". The North American F-86K *Sabres* destined for the Royal Netherlands Air Force cannot, it maintains, be regarded as serviceable all-weather fighters for countries where bad weather prevails, as their radar equipment is not sufficient for extreme weather conditions. Moreover the F-86K is a single-seater and is very difficult for one pilot alone to fly under adverse meteorological conditions.—Lieutenant-General A. Baretta, Chief of the Air Staff, stated on his return from a visit to the United States that the F-86K had to be chosen, since no other all-weather fighter was available. The F-86K, he added, is being equipped with the new MG-4 radar, though it seems doubtful whether this will be installed in the European-built machines.

AIR TRANSPORTATION

● New I.A.T.A. Atlantic cargo rates

Basic agreement on air cargo rates has now been reached between the scheduled airlines operating over the North and central Atlantic. Neither the I.A.T.A. General Meeting in Paris in the autumn of 1954 nor the Traffic Conference in Venice succeeded in settling the problem. The new rates still have to be approved by the Traffic Conference to be held in the Eastern United States next September. Under the new agreement, present basic general cargo rates remain unchanged, but their application to specific types of cargo will be revised in order to encourage traffic and simplify selling. Present I.A.T.A. cargo rates will remain effective until July 1st, when a new " commodity rating system " will be introduced, under which the several thousand existing special rates will be cut down to less than 50.

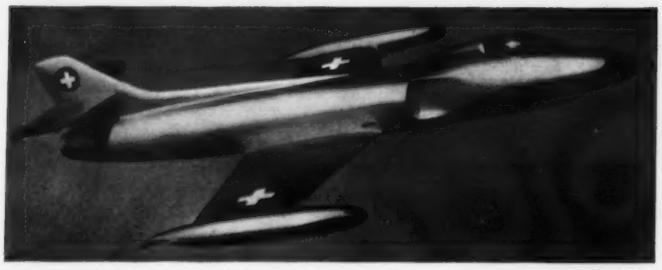
Future Lufthansa crews receiving instruction in the operation of the *Super Constellation* from Lockheed instructor Dwight A. Chatterton at Burbank, California.

An escort of U.S. Navy Sikorsky S-55 helicopters for the aircraft carrier *Princeton* during an anti-submarine exercise.

● U.S. airline subsidy declining

In hearings before a Senate Appropriations sub-committee, C.A.B. member Chan Gurney has shown that the dependence of U.S. airlines on mail pay and Government subsidy is declining. Proportion of mail pay and subsidies in the airlines' overall revenue was 31.5 % in 1940, 12.7 % in 1951 and 9.5 % in 1954. Share of subsidies in mail pay declined from 63 % in 1951 to 57 % in 1954 and would probably be no more than 53 % in 1955.

* Extracts from *Interavia Air Letter*, daily international news digest, in English, French and German. All rights reserved.



Model of the single-jet P-16 fighter and ground attack aircraft designed by the Swiss firm of Flug- und Fahrzeugwerke Altenrhein.

● **K.L.M. orders Douglas Seven Seas**

K.L.M. Royal Dutch Airlines has signed a contract with Douglas Aircraft Co. for ten Douglas DC-7C *Seven Seas*, to be delivered starting in the spring of 1957, company President Aler announces. Total price is given as roughly $30,000,000. It has not yet been announced on what routes the DC-7Cs will be used, though they would enable K.L.M. to fly non-stop from Amsterdam to New York. K.L.M. has purchased all DC types since the DC-2 first came out in 1934 (DC-2, DC-3, DC-4, DC-5, DC-6, DC-6A, DC-6B, DC-7C).

INDUSTRY

● **British and American aircraft exports**

" Planes ", the official publication of the Aircraft Industries Association of America, states that the United States exported aircraft, engines and equipment to a value of $539,604,000 during the first ten months of 1954, compared with British exports of similar products totalling $156,940,904 for the full year.

● **America's atomic-powered aircraft project**

The Joint Congressional Committee on Atomic Energy has urged the Air Force to " go all out " on development of the atomic-powered aircraft project. — The Committee was very impressed by a recent inspection of the *Nautilus* atom-powered submarine of General Dynamics Corporation (Electric Boat Division).

● **Israel orders 15 Mystère IIs**

Fifteen *Mystère II* jet fighters have been ordered from Société Marcel Dassault for the Israeli Air Force. This is the third order payable in foreign currency received by the company (72 *Ouragans* have been supplied to India, 225 *Mystère IVs* are in production under offshore orders). Deliveries of *Super Mystères* to the French Air Force are to begin in 1957.

● **Radio Navigation Congress in Munich**

The German Radio Navigation Committee (part of the Association for the Promotion of Transport) is to hold an international radio navigation conference in Munich during its Annual General Meeting from June 1st to 4th, 1955. — Subjects for discussion : practical pilot experience, long-distance navigation, en-route, approach and landing radio navigation, meteorological radio navigation, celestial radio navigation, etc. The Meeting will be rounded off by an exhibition and practical demonstration of radio navigation equipment and accessories.

● **" All or nothing . . . "**

It has been suggested by certain members of Germany's " Gesellschaft für Weltraumforschung " (Society for Astronautical Research) that the Society should change its name. Professor Karl Schütte, First President, has now sent a circular letter to all members strongly opposing the suggestion. He points out that the present name enjoys international recognition and renown. The change in name, he adds, would also indicate a change in the Society's aims—implying for example a limitation of its work to the field of jet propulsion—whereas it should continue to handle all problems connected with space travel.

FLYING EQUIPMENT

● *Avro Aircraft Ltd.* (Malton, near Toronto) has built a number of CF-100 *Canuck* twin-jet all-weather fighters as target tugs for the Royal Canadian Air Force, to meet the latter's request for a high-speed high-flying target for the training of fighter pilots and anti-aircraft units.

● The *Fairchild Aircraft Division* of Fairchild Engine and Airplane Corp., of Hagerstown, Maryland, has submitted to the U.S. Navy a project for a Navy version of the *Fairchild C-123B* twin-engined assault transport, to be equipped for carrier operations and the carriage of men and materials. Provisional calculations show that the type could carry a payload of about 8 tons over a range of 1,200 nautical miles, or 4 tons over 2,100 nautical miles.

● Convair has equipped a twin-engined *Convair Liner 340* experimentally with much more efficient cabin sound-proofing and is working on aerodynamic refinements aimed at increasing cruising speed. A marked reduction in noise level in the cabin has been obtained by replacing the conventional jet exhaust pipe by a rectangular-section pipe. The loss in speed caused by the elimination of the thrust augmenting pipe has been compensated by improved design of the engine nacelles. " Acoustomat Tape " has been applied in several layers to the inside of the fuselage, and the whole cabin has been given an additional inch of fibreglass sound-proofing material. Additional insulation has also been provided for the forward cabin windows.

To reduce noise level in the Convair Liner 340's cabin additional fibreglass insulation has been installed and the normal circular jet augmenter tubes replaced by rectangular exhaust openings.

● *S.N.C.A. du Sud-Est's* Toulouse plant is working day and night on the *SE. 210 Caravelle* twin-jet commercial transport, so that first ground tests can begin early in May. The SE.210 is fitted with two *Avon RA.26s*.

● *S.N.C.A. du Nord* has worked out specifications for a version of its *Noratlas* twin-engined commercial and military transport to be fitted with Pratt & Whitney R-2800-CB.17 *Double Wasps* (the aircraft is normally powered by two SNECMA-Bristol *Hercules 738* engines of 2,000 h.p. each) ; P & W R-2800-CB.17 deliver a take-off power of 2,500 or 2,200 h.p. with and without water injection.

● *F.G. Miles Ltd.* is fitting a Miles *Aerovan* freighter (two Blackburn *Cirrus Major* engines of 155 h.p. each) with a Hurel-Dubois high-aspect-ratio wing. It is expected that performance will be considerably improved.

● Two prototypes of the P-16 jet-powered fighter and ground attack aircraft are in construction at *Flug- und Fahrwerke Altenrhein*, Switzerland. The first is already nearing completion. Power plant will be an axial-compressor turbojet. The P-16 is to have powerful armament and feature particularly short take-off and landing runs.

EQUIPMENT AND ACCESSORIES

● Auxiliary turbine engines, as built in large numbers by *AiResearch Division* of The Garrett Corporation (starters for jet engines, auxiliary drives, etc.) are now supplied with a guarantee of reliable operation up to altitudes of more than 53,000 ft. Operating time between overhauls is given as 1,000 hours for the newest equipment.

● *Republic Aviation Corp.* announces development of a new ejection seat which could become standard equipment for the majority of military aircraft in service today. Republic has granted production and sales rights to Aircraft Mechanics Inc., of Colorado Springs, and plans to offer the seat to N.A.T.O. air forces in Europe through the Republic Aviation International S. A., Lugano, Switzerland. — The new seat is to be installed in the F-84F *Thunderstreak* fighter and the RF-84F *Thunderflash* fighter reconnaissance aircraft.

CONGRESSES

● The *Third International Transport Congress* is to be held in the Palazzo San Giorgio, Genoa, from October 9th to 12th, 1955, Dr. Ing. Salvatore Tomasino, Secretary General of the Centro por lo Sviluppo dei Trasporti Aerei, announces. Professor Vincenzo Arangio-Ruiz, President of the Accademia dei Lincei, will read a paper on " Materia e spirito nel progresso delle communicazioni ".

Book Reviews

Frontier to Space. — By Eric Burgess. With a foreword by the Astronomer Royal Sir Harold Spencer Jones. Chapman & Hall, London, 1955. (English, 174 pages, price 21 shillings).

An account of the progress made during the past decade in rocket construction and research in the upper air layers. The title alone warns againt exaggerated optimism, suggesting that the " extra-terrestrial terrain " has to be conquered yard by yard. It cannot be denied, for example, that the highest two-stage rocket has so far reached no further than 250 miles above the earth, while the moon is still some 240,000 miles away. A special merit of this book is its conscientious examination of widely scattered periodical articles, reference to which is greatly facilitated by the detailed bibliography attached to each chapter. He.

Leitfaden der Fernlenkung. — By Dipl.-Ing. F. Müller. Volume 2 in the series of textbooks issued by the German Radio Navigation Committee. Editor Prof. L. Brandt. Publisher Deutsche Radar-Verlagsgesellschaft, Garmisch-Partenkirchen, 1955. (German, 200 pages, price DM 22).

Although based principally on developments during the closing years of the war, this book is of great present interest. Guided missiles are taking a more and more important place in the arms planning of all countries, and high frequency engineering occupies a key position in this development. Whereas, however, the latest electronic processes and equipment for guidance are kept strictly secret in both West and East, Germany's former developments are well known on both sides and can therefore be discussed openly. And these developments reveal quite a lot about present trends in guidance technique...

The author, who himself held a leading position in guidance engineering, has collected and systematically evaluated all available documents. His harvest is astonishing. For example, extensive details of German command guidance systems, their modulation processes and practical forms (e. g., *Kehl/Strassburg* and *Kogge* radio guidance systems) and of cable guidance systems (e.g., *Goliath* and *Dortmund/Duisburg*) have been recalled from oblivion. Mention is also made of a number of acoustic target-seeking heads, such as *Dogge* (for the X.4), *Zaunkönig* (for torpedoes), etc., and infra-red target-seeking heads, such as *Hamburg* (for *Wasserfall*) and *Madrid* (for *Enzian*). A description of automatic fuses (proximity fuses) and of several automatic guidance processes rounds off the picture of this healthy young branch of engineering.

The author has made a point throughout of clear statement, so that his book also forms a valuable reference work for the non-specialist. Altogether a book that deserves and should get considerable attention, not only in Germany but also elsewhere. Ri.

Internationale Luftfahrtabkommen — Vol. II. — Edited by Professor Alex Meyer, in the German Air Law Research Centre's series of publications. Carl Heymanns Verlag, Cologne-Berlin, 1955 (German ; 116 pages, price DM 12.50).

A welcome addition to the collection of texts of international air agreements in German, issued by the head of the Air Law Research Centre of the University of Cologne. Professor Meyer also attended the discussions at which common official German translations of a number of texts were agreed upon by Germany, Austria and Switzerland. The present Volume II covers I.A.T.A.'s conditions of carriage, the Geneva Convention on International Recognition of Rights in Aircraft, the Rome Convention on Damage caused by Foreign Aircraft to Third Parties on the Surface and the Chicago International Air Transport Agreement. He.

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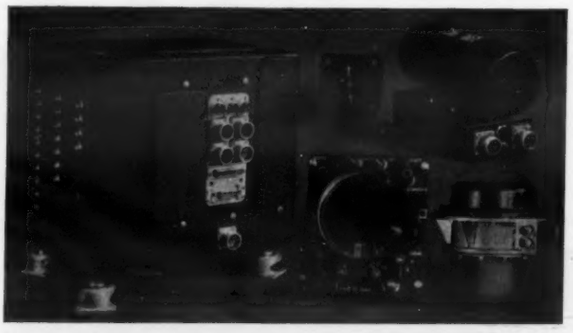

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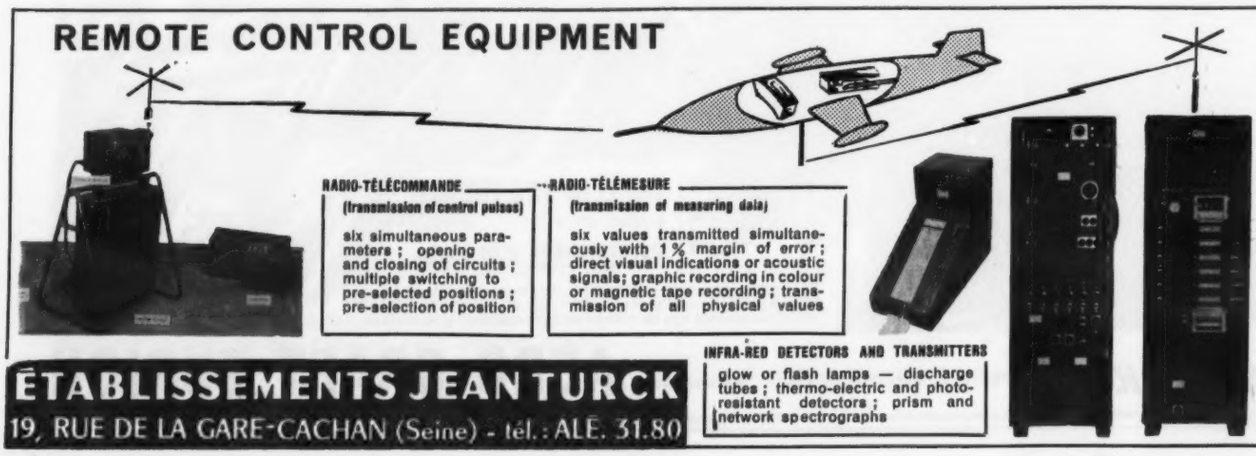

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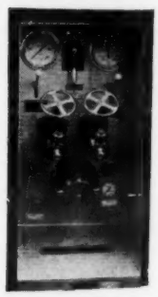

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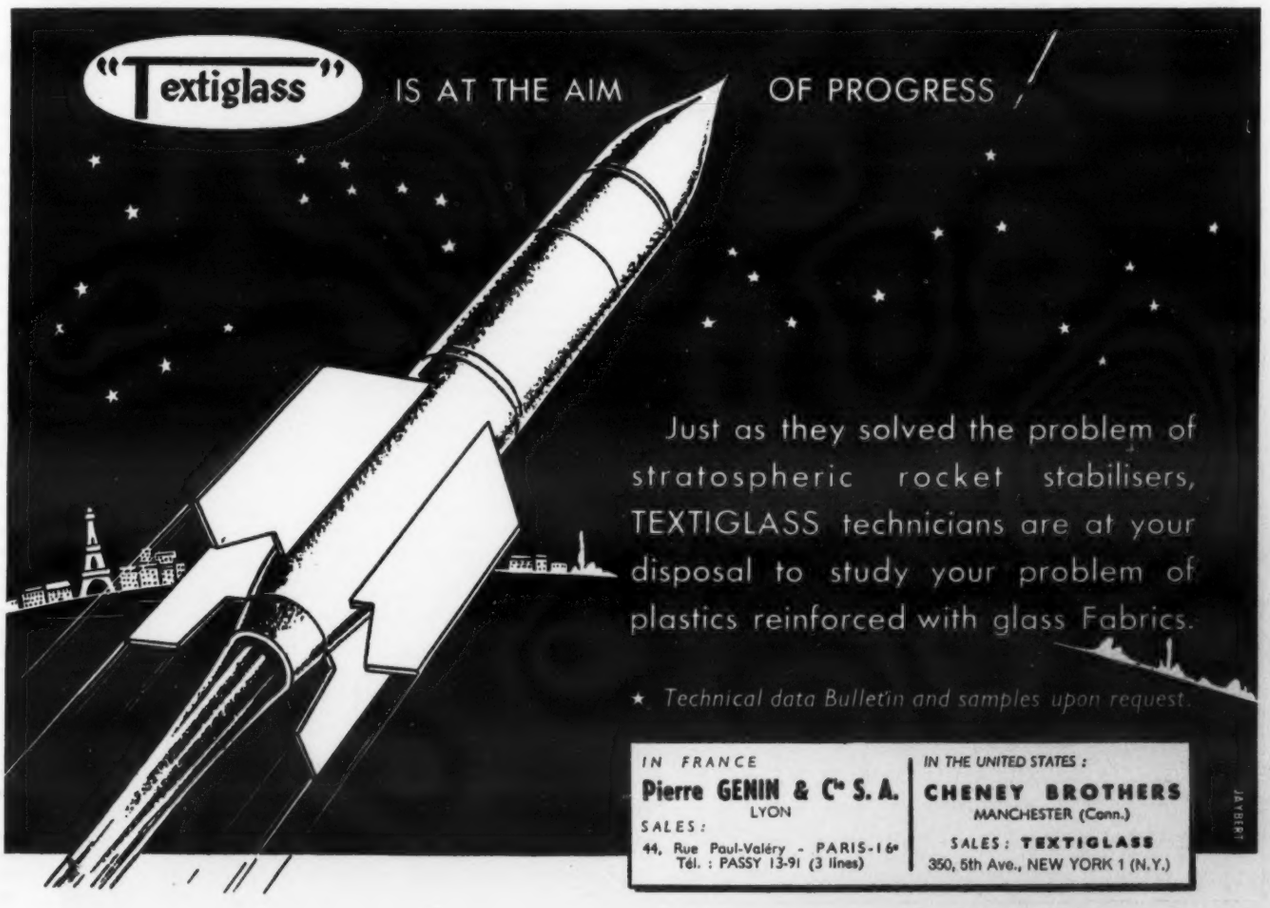
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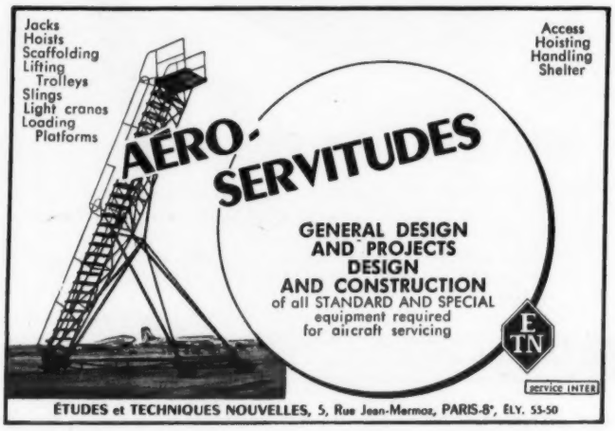

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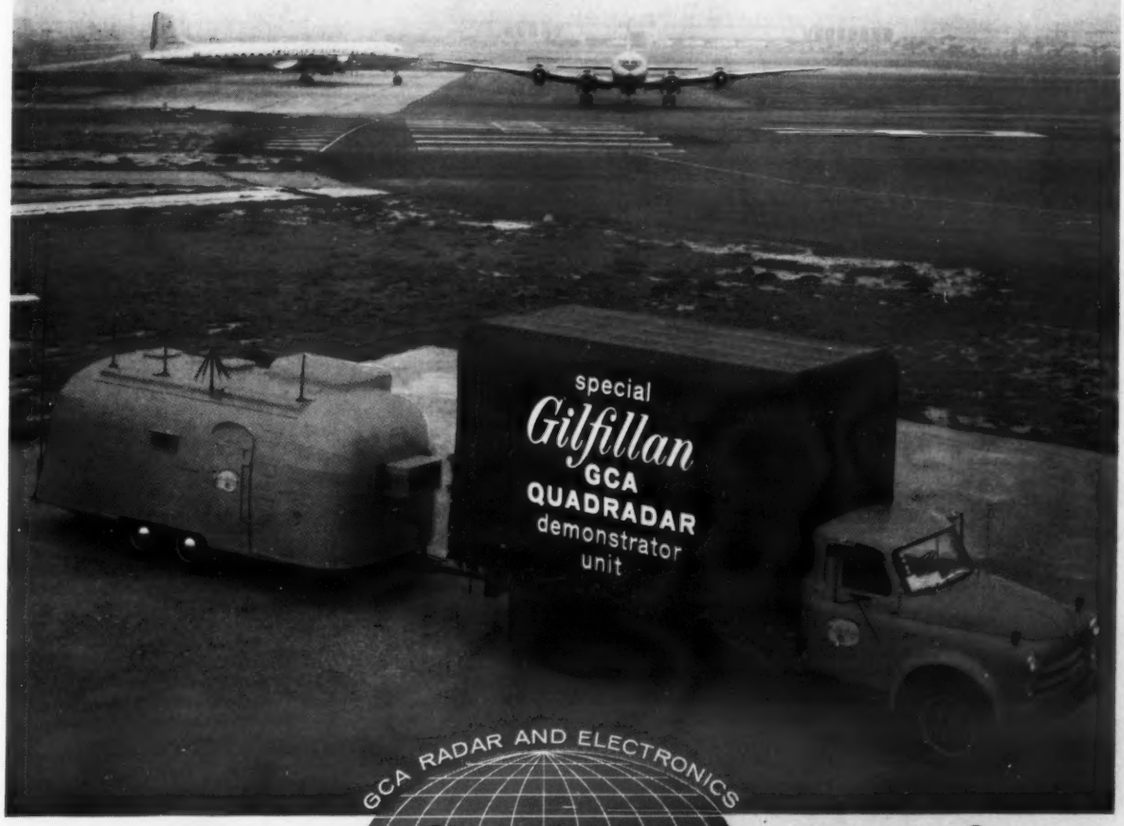

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